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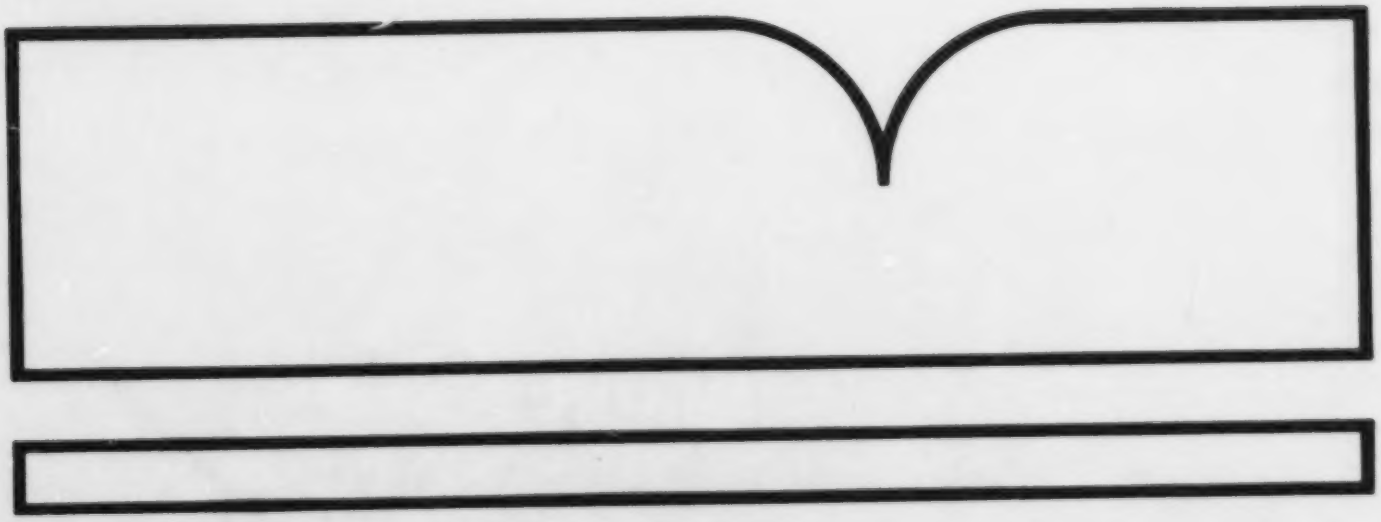
The Removal of Trace Organics from Drinking Water Using Activated Carbon and Polymeric Adsorbents

Missouri Univ.-Columbia

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

May 81



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THE REMOVAL OF TRACE ORGANICS FROM DRINKING WATER USING ACTIVATED CARBON AND POLYMERIC ADSORBENTS

by

John T. O'Connor, Diane Badorek, and Leon Thiem
University of Missouri-Columbia
Columbia, Missouri 65201

Grant No. R-804433

Project Officer

O. Thomas Love, Jr.
Drinking Water Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

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16. ABSTRACT
A pilot plant was operated at the Kansas City Missouri Water Treatment Plant to study adsorption as a means of removing trihalomethanes and total organic carbon from drinking water. The pilot plant consisted of 15 columns 6 inches in diameter and each containing about a 3 ft depth of a granular adsorbent. Granular activated carbons and polymeric adsorbents were compared in four extended tests conducted over periods of 183, 111, 65 and 129 days. The pilot plant studies demonstrated the effects of regeneration, variations in trace organic concentration, and depth of adsorbent on trace organic removal including effluent concentration and adsorption capacity.

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

Low but potentially significant concentrations of organic matter in water including known and suspected carcinogens have stimulated the investigation of a variety of adsorbents capable of removing these compounds from water. Part Two of this report describes the pilot plant studies that were conducted to compare the performance of a variety of adsorbents for use in treating water. The laboratory studies used in selecting adsorbents for the pilot plant were described in Part One and the overall results will be summarized in Part Three.

Francis T. Mayo, Director
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ABSTRACT

A pilot plant for the treatment of drinking water was constructed to study the removal of trihalomethanes and total organic carbon by adsorption onto a variety of granular activated carbons and resin adsorbents. The pilot plant was located at the Kansas City, Missouri, Municipal Water Treatment Plant and thus utilized a treated surface water as an influent source. Construction materials included stainless steel, glass, and teflon - all materials that would not contribute organic compounds to the water passing through them.

One of the primary objectives of the study was to compare the capacity of adsorbents for removing trihalomethanes, total organic carbon, and odor from drinking water. Some of the adsorbents underwent at least two regeneration cycles to determine the effect of thermal reactivation on adsorption capacity. In one case, steaming was performed periodically to suppress the development of biological growth on the surface of the adsorbent and to observe the effect on trihalomethane adsorption. Standard plate count analyses were performed on media samples taken at the conclusion of each phase of the study. The study was conducted over a period of 21 months to experience the seasonal effects on trihalomethane formation and total organic carbon composition.

During the four phases (exhaustion cycles) of the study, two commercially available granular activated carbons manufactured from different source materials were compared simultaneously in the virgin, once-regenerated, and twice-regenerated states. These materials were placed in deep-bed contactors so that media depths as great as 9 feet could be studied. Several other granular activated carbons manufactured from different source materials, including an experimental domestic product and a European product, were studies at media depths up to 3 ft. Three types of resin adsorbents--weak-base anion exchange, strong-base anion exchange, and carbonaceous were compared directly with the activated carbons.

This report was submitted in fulfillment of Contract No. R-807433 by the University of Missouri-Columbia under the sponsorship of the U.S. Environmental Protection Agency. The report covers the period September 1976 to March 1979, and work was completed as of October 5, 1979.

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We also wish to acknowledge the many carbon and resin manufacturers who participated in this study and donated their products as well as their advice and expertise.

SECTION 1

INTRODUCTION

About a decade ago, the American Water Works Association (AWWA) created a research foundation to foster applied research meaningful to water utility managers and operators. A list of important research needs in the areas of water supply and treatment was developed by the AWWA Research Foundation by soliciting information from utility managers around the country on their current problem areas. This research project is the first to have received the support of the Research Foundation because of the high priority assigned to it by most water utilities. The sources of support for this project include the AWWA Research Foundation, 14 major U.S. water utilities that were participating directly in the project, and the U.S. Environmental Protection Agency.

This project encompasses a water quality survey involving 14 water utilities from many parts of the country, a bench-scale study of various adsorbents currently available for the removal of chlorinated organic compounds from drinking water, and a pilot plant demonstration of the feasibility of using these materials as viable treatment methods for the protection of public water supplies.

Three universities were involved in the study. Iowa State University conducted the analyses for trihalomethanes and other chlorinated organic compounds in conjunction with the water quality survey of the 14 participating utilities. ISU contributed some analytical support for the pilot plant phase of the project. The University of Illinois conducted a series of laboratory investigations in which adsorption isotherms were developed for the various adsorbents included in the pilot plant study. The University of Missouri-Columbia, under the direction of Dr. John T. O'Connor, developed the experimental protocol for the pilot plant study in addition to designing, constructing, and operating the pilot plant installed at the Kansas City, Missouri, Water Treatment Plant.

It should be noted that the Kansas City Water Department was one of the 14 utilities that participated in the water quality survey and was also willing to host the pilot plant portion of the project. This commitment to provide additional resources and manpower in terms of space, operational assistance, and laboratory support for the pilot plant amounted to a very substantial contribution to the project.

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SECTION 2

CONCLUSIONS

GENERAL CONCLUSIONS

In studies using pilot plant adsorption columns to adsorb halogenated organic substances from softened, filtered Kansas City water, activated carbon and carbonaceous resin were able to remove trihalomethanes (TTHM) for extended periods. Conversely, strong and weak base anion exchange resins were not able to remove the trihalomethanes. Only the granular activated carbons were found to be effective in removing significant amounts of the total organic carbon (TOC) present. Periodic steaming of the activated carbon columns was found to reduce bacterial growth and enhance TTHM and TOC removal. Regular backwashing of the activated carbon columns was also found to be effective in reducing the accumulation of bacterial growth.

Little or no difference was observed in removals obtained by columns of twice-reactivated, once-reactivated, and virgin activated carbons, indicating that calcium carbonate deposits from lime-softened water did not coat the adsorbent and impair its adsorption capacity.

PHASE I RESULTS

Over an initial period (Phase I) of 133 days, a 3-ft bed of bituminous-base granular activated carbon (Westvaco WVG) removed 70% of the influent TTHM. Nine feet of Westvaco WVG were required to remove 99% of the influent TTHM. A 3-ft deep bed of a carbonaceous resin (Rohm and Haas Ambersorb XE-340) provided 98% TTHM removal during the same period. Steaming of a three-foot bed of Westvaco WVG increased TTHM removal to 87% whereas steaming of the weak base anion exchange resin (Diamond Shamrock ES-561) had no significant measurable effect on an initially low removal. However, the periodic steaming of the Westvaco WVG markedly reduced the number of microorganisms recovered from the adsorbent from 89,000 to 5,800 colonies/gram.

Throughout Phase I, the influent concentration of TTHM steadily increased from less than 10 µg/l (February) to over 80 µg/l TTHM (June) as influent water temperature increased. An important outgrowth of the present study was the establishment of the seasonal pattern of TTHM formation in the finished water at Kansas City. This facilitated subsequent decisions as to when virgin and regenerated adsorbents should be placed in service.

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PHASE II RESULTS

During Phase II, all 15 pilot plant columns were in operation, allowing the comparison of the performance of the carbons made from bituminous coal, lignite, peat, and petroleum. TTHM levels had increased to a peak of approximately 200 µg/l in the late summer, establishing a pattern that was to be repeated in the following year. This maximum TTHM level provided a more significant challenge for the adsorbents than was present in Phase I. Over the 111 days of Phase II operation, the TTHM removals were comparable to those observed during the first 111 days of Phase I with 80%, 83%, 82%, 85%, and 68% removals by bituminous, lignite, petroleum, bituminous base carbon enhanced for TTHM removal and extruded peat base carbon, respectively.

Steaming of the Westvaco WVG column again increased TTHM removal. The steamed column removed 92% of the TTHM over a period of 111 days, exactly equalling the percent removal observed over the first 111-day period of Phase I.

Once again, the Ambersorb XE-340 was effective in removing 90% of the influent TTHM while the Diamond Shamrock ES-561 continued to be erratic and generally ineffective. As a result, the Diamond Shamrock ES-561 was eliminated from further pilot plant testing.

Phase II provided an additional important contrast which was missing in Phase I since equipment for the measurement of TOC was not initially available. With the acquisition of one of the first low-level TOC analyzers manufactured, column removals of influent TOC could be measured. The 3-ft deep beds of granular activated carbon removed 51%, 37%, 30%, 19% and 45% TOC for the bituminous, lignite, petroleum, bituminous carbon enhanced for TTHM removal, and extruded peat base carbon, respectively. It became evident that there were far greater differences in carbon performances with respect to TOC than with respect to the removal of the small amounts of TTHM present in the influent. Moreover, the Calgon carbon developed for enhanced capability for TTHM removal did achieve superior removal of TTHM but at the expense of reduced TOC removal capability. Apparently, the pore size distribution which results in more effective TTHM removal retards the removal of a range of other, larger adsorbates. Steaming of the Westvaco WVG column appeared to increase TOC removal modestly to 56%.

Neither Diamond Shamrock ES-561 nor Ambersorb XE-340 exhibited any significant TOC removal capability, indicating that these resins could not be employed independently for broad-spectrum removal of organic contaminants.

Perhaps most significant was the observation that the 9-ft depth of Westvaco WVG was incapable of removing more than 75% of the influent TOC at the 2 gpm/ft^2 application rate. The low column removals from influent levels of approximately 3 mg/l TOC were disappointing and threatened to make it impossible for a 3-ft bed of any granular activated carbon to meet the proposed USEPA requirement of 50% initial TOC removal.

Bacteria dislodged from adsorbents at the end of Phase II were uniformly low, probably as the result of the low December water temperatures.

At the end of Phase II, the bituminous and lignite base carbons were returned to the respective manufacturers for thermal reactivation in preparation for a study of the effect of reactivation on adsorbent performance.

PHASE III RESULTS

The reactivation of the carbons resulted in the restoration of their virgin adsorption capacity, as measured by Iodine Number and Decolorizing Index. During Phase III of the study, comparisons of TOC removal indicated similar performance between 3-ft beds of Westvaco WVG whether it was a once-reactivated (60%), virgin (62%), or regularly backwashed virgin (61%) product. Once-reactivated and virgin lignite base carbon (ICI HD 1030) removed 43% and 51% of the TOC, respectively, over the period of Phase III.

No steaming was practiced during Phase III. Moveover, since the influent concentrations of TTHM were generally less than 5 µg/l, little information on TTHM removal was obtained. As a result, Phase III was terminated after only 65 days so that Phase IV could be initiated immediately prior to the time when the maximum TTHM influent concentration was expected, based on the previous year's seasonal pattern.

The Ambersorb XE-340 was again demonstrated to be ineffective in TOC removal during Phase III while a 3-ft deep bed of a strong base anion exchange resin (Rohm and Haas Amberlite IRA-904) appeared to remove roughly one-third of the influent TOC. Another bed of a different strong base anion exchange resin (Diamond Shamrock A-162) removed 47% of the influent TOC. On a weight basis, Diamond Shamrock A-162 was only one-half as effective as a single 3-ft deep bed of Westvaco WVG activated carbon.

The Ambersorb XE-340 was placed first in the series of three columns to observe the effect of high molecular weight components of TOC on the adsorption of TTHM by the resin. Laboratory studies had indicated that high molecular weight organic substances might be irreversibly adsorbed to the carbonaceous resin leading to "fouling" and loss of TTHM removal capability. Since this resin is still under development and evaluation, the manufacturer was uncertain of the appropriate regeneration procedure. As a result of subsequent USEPA studies, a far more vigorous steaming procedure is now being recommended for the Ambersorb XE-340 than was recommended at the time of the present study.

TON REMOVAL

A major objective of the overall study was an evaluation of the removal of taste- and odor-producing compounds as measured by threshold odor number (TON). However, the influent TON values were consistently low, making clear-cut evaluations of the removal of odor-producing compounds extremely difficult.

EFFECT OF BACKWASH

Large numbers of microorganisms were dislodged from the adsorbents at the end of Phase III in June 1978. The inert sand media and the resins harbored few microorganisms whereas the activated carbon supported significant growth, particularly in those columns that had removed the most TOC. Backwashing of a virgin Westvaco WVG column resulted in more than an order of magnitude reduction in bacterial count, from 850,000 colonies/gram on the undisturbed column to 52,000 colonies/gram on the backwashed Westvaco WVG column, indicating the effectiveness of backwash in controlling accumulations of organisms.

PHASE IV RESULTS

Westvaco WVG and ICI HD-1030 were both reactivated to levels beyond their virgin capacities by the manufacturers in preparation for Phase IV. This resulted in TTHM removals of 75%, 67%, and 66% (67%) by 3-ft deep beds of twice-reactivated, once-reactivated and virgin (virgin, replicate) Westvaco WVG. The regularly steamed column of virgin Westvaco WVG removed 96% of the influent TTHM over the 129-day period.

The twice-reactivated, once-reactivated, and virgin ICI HD-1030 removed 77%, 72%, and 62% of the influent TTHM. Again, the reactivation of this activated carbon beyond its virgin capacity resulted in slightly enhanced TTHM removal.

TOC removals were marginal, as before. The 3-ft deep beds of Westvaco WVG, twice-reactivated, once-reactivated, virgin, and virgin (replicated) removed 55%, 50%, 56%, and 53%, respectively. Steaming increased the TOC removal of the virgin Westvaco WVG to 63%. Nine feet of the twice-reactivated Westvaco WVG removed a total of 78% of the TOC from fairly constant influent levels of 2 mg/l. The 3-ft deep beds of ICI HD-1030, twice-reactivated, once-reactivated and virgin, removed 39%, 38% and 36% of the influent TOC. Nine feet of the ICI HD-1030 removed just under 58% of the TOC.

The Ambersorb XE-340 was regenerated after each of the first three phases with one and a half bed volumes of low pressure (12 psig) steam. Despite this procedure, the performance of the Ambersorb XE-340 declined. In Phase IV, at the higher (10 gpm/ft^2) application rate, Ambersorb XE-340 removed only 54% of the influent TTHM and 5% of the influent TOC. As observed a year earlier, the cool (November) water temperatures suppressed organism growth on all of the adsorbents.

Overall, the influent adsorbate concentrations and column removals were consistent between replicates, in successive phases of operation and with successive regenerations. Granular activated carbon exhibited the potential for prolonged removal of both trihalomethanes and total organic carbon.

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SECTION 3

RECOMMENDATIONS

The removal of organic constituents from drinking waters is desirable for reducing tastes and odors, controlling bacterial growths in distribution systems and, most important, for protection against potentially toxic synthetic organic chemicals. While water treatment plant processes can be modified in an effort to maximize the removal of organic substances and to minimize the production of trihalomethanes, reductions are incomplete.

On the basis of the pilot-plant studies conducted at Kansas City, Missouri, it appears that adsorbents such as granular activated carbon are effective in achieving a substantial, though not complete, removal of trihalomethanes and total organic carbons for periods of several months or longer. Since shallow, 3-ft-deep beds of granular activated carbon were effective and did not lose adsorption capacity because of calcium carbonate deposition, regeneration, or high pH, the replacement of filter media with granular activated carbon seems feasible.

While not conclusive, the data from the Kansas City study indicate that an adsorption bed that is receiving a relatively constant low-level influent concentration of organic substances is able to respond to remove instantaneous high concentrations such as might be encountered during an accidental spill. The implication is that adsorption beds can offer long-term protection against accidental spills even when they appear to be exhausted.

It is therefore recommended that granular activated carbon adsorption be considered an effective process for the removal of a broad spectrum of organic substances, including the trihalomethanes. Moreover, the replacement of filter media with granular activated carbon may be sufficient to provide water suppliers with additional safeguards against accidental spills for prolonged periods.

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SECTION 4

PILOT-PLANT DESIGN AND OPERATION

CONSTRUCTION MATERIALS

The pilot plant was constructed of materials that would not contribute organic compounds to the water passing through it. As a result, glass was used for the pilot plant columns that would subsequently hold the adsorbent materials; stainless steel or glass was used for piping, valves, regulators and flowmeters; and Teflon was used for end plates, seals, and other packings.

DESIGN

The pilot plant consisted of 15 glass columns, each 6 in. in diameter and 6 ft in length. One-inch-thick Teflon was machined into end plates for the columns. Both the top and bottom end plates had 100 mesh stainless steel screen backed by 10 mesh stainless steel screen covering the inlet and outlet of each column to prevent loss of the adsorbents. The columns, grouped in a module consisting of three columns, were supported by a redwood frame and made up an independent unit. The columns in three of the units were operated in series; those in the two remaining units were operated in parallel. All of the columns were designed to function as downflow contactors and were connected to a common influent manifold. Grade 304 stainless steel pipe was used throughout the pilot plant. The pilot plant as originally built consisted of 12 columns (see Figure 1). Three columns were added later.

The flow through each column or each group of columns in series was regulated by stainless steel needle valves and was monitored by stainless steel and glass flowmeters. Additional flowmeters were located on the backwash line of each unit. Stainless steel dairy pumps were employed to deliver the influent to the pilot plant.

Because of pressure limitations on the glass columns, it was necessary to place a pressure regulator made of stainless steel and Teflon between the pumps and the pilot plant to ensure that the columns would not be broken. As an added safety measure, pressure relief valves and water hammer standpipes were installed on each column.

OPERATION

The pilot plant received treated water from the Kansas City Water Treatment Plant that had been filtered but not post-chlorinated. However, chlorine and ammonia were added early in the plant water treatment scheme,

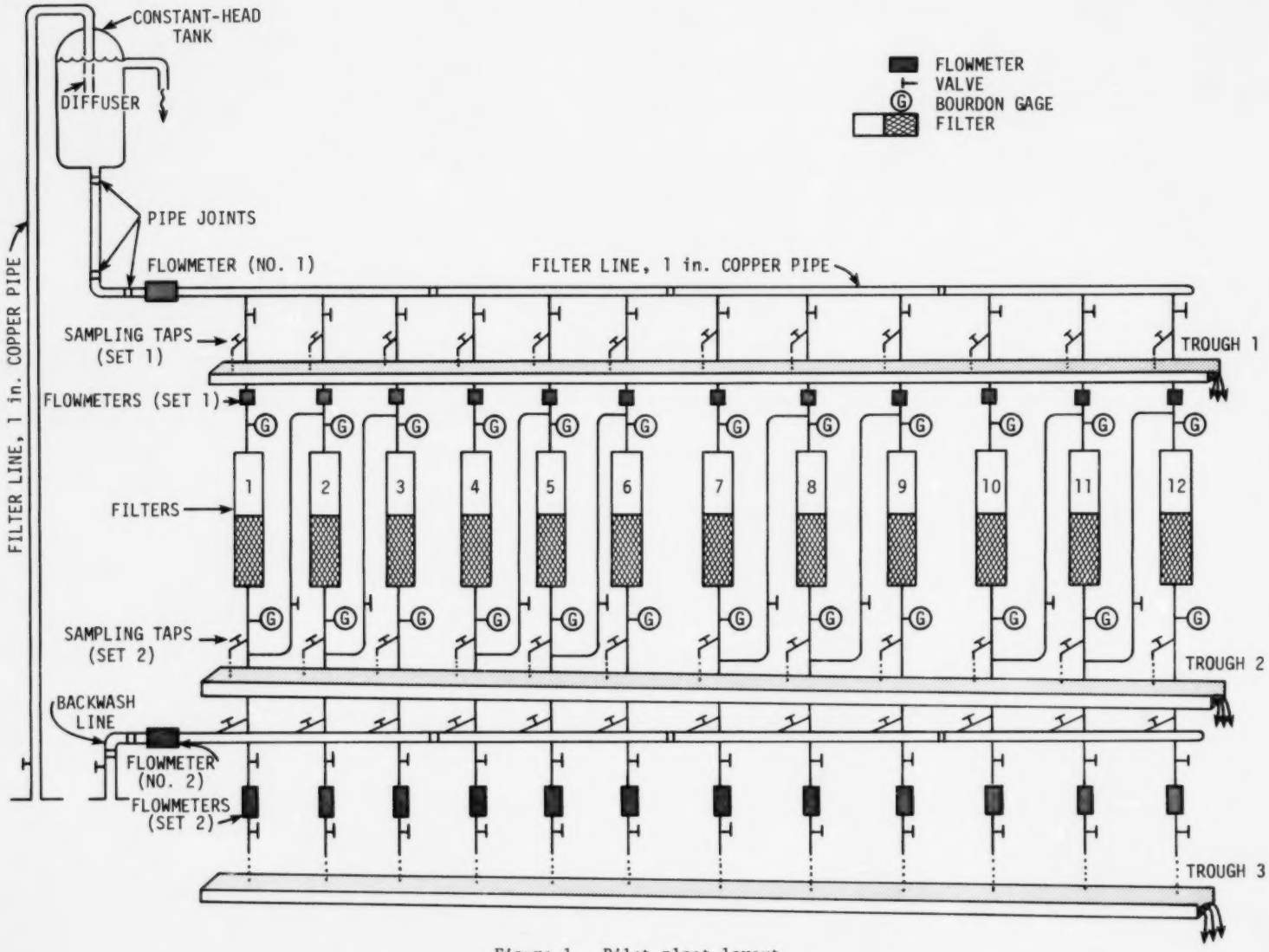

Figure 1. Pilot plant layout.

resulting in trihalomethane formation in advance of filtration. The pilot plant was placed in the position in which it was anticipated that an adsorption process for the removal of dissolved organic compounds would be located in the treatment scheme of a typical softening plant.

In Phases I and II, each column contained a 3-ft bed of an adsorbent (0.6 ft^3) material supported by approximately a 3-in. layer of small gravel. The surface application rate of the influent water was 2 gpm/ft^2 of media (0.4 gpm total flow), which resulted in an empty bed contact time of 11.2 min. In Phases III and IV, the carbon in several of the columns was thermally regenerated, and the volume of material was thereby reduced. In these cases, the flow rates were reduced to compensate for the reduction in volume and to maintain a constant empty bed contact time throughout the study. No virgin material was added to make up for the change in volume.

INFLUENT TO PILOT PLANT

The Kansas City, Missouri, Water Department obtains roughly three-quarters of its raw water from the Missouri River and the remainder from a well field in the Missouri River aquifer. The water is first treated for the removal of suspended solids by coagulation, flocculation and sedimentation. Chlorine, potassium permanganate, inorganic (alum) and polymeric coagulants are added in this clarification stage. Thereafter, the clarified water is treated with lime, soda ash, ammonia and powdered activated carbon just prior to the softening basins. After settling of the softening sludge, the water is recarbonated. This process is followed by a second stage of coagulation, flocculation and sedimentation. Filtration is followed by post-chlorination to establish a combined chlorine residual.

The softened and filtered water may be roughly characterized as having a hardness of 120 mg/l as $CaCO_3$ equivalent, an alkalinity of 60 mg/l as $CaCO_3$ equivalent and a pH of 10. Kansas City Treatment Plant laboratory data and chemical additions during the period of this study are given in Appendix D.

SECTION 5

EXPERIMENTAL PROTOCOL

PROJECT GOALS

The pilot-plant study was designed to facilitate comparisons of the capacities of several adsorbents, some carbonaceous and some polymeric in nature, for removing trihalomethanes and a broad spectrum of organic compounds from drinking water. To accomplish this objective, the pilot plant was scheduled to operate for at least a year so that the effect of seasonal changes on trihalomethane formation and TOC and TON make-up could be studied.

For most of the adsorbents, a 3-ft deep bed was considered to be representative of a full-scale operating situation. For a few adsorbents, additional bed depths of 6 and 9 ft were monitored to investigate the effectiveness of deep-bed contactors.

Granular activated carbons manufactured from different source materials and three special-purpose resins were included in the pilot-plant study. Table 1 summarizes the identities of the adsorbents used in each column during each phase of the study while Table 2 provides data on their physical properties as adsorbents.

Phase I

During Phase I only 8 of the 16 columns were in operation. During this phase, Columns 1 through 6 and 14 and 15 were filled with 0.6 ft^3 of the various adsorbents. Columns 1, 2, and 3 were operated in series and contained virgin Westvaco WVG, a high-activity bituminous base granular activated carbon. Columns 4, 5, and 6 were also operated in series. The first two columns contained virgin Diamond Shamrock ES-561, a weak-base anion exchange resin; and the third contained virgin Ambersorb XE-340, a carbonaceous resin. Column 14 contained virgin Westvaco WVG (periodically steamed in order to inhibit biological growth on the media) and Column 15 contained ES-561 (also periodically steamed).

Phase II

During Phase II, which began August 26, 1977, and ended December 15, 1977, all 15 columns were in operation. Because the duration of Phase II was somewhat shorter than that of Phase I, the results for Phase I are discussed in terms of both a 111-day and a 133-day period of operation so that a more direct comparison can be made with the data collected during the 111-day span of Phase II.

TABLE 1
IDENTIFICATION OF ADSORBENTS UTILIZED IN KANSAS CITY, MISSOURI
PILOT PLANT EVALUATION OF REMOVAL OF ORGANIC SUBSTANCES FROM DRINKING WATER

Column	Phase I I (133 days) Feb.-Aug. '77	Phase II II (111 days) Aug.-Dec. '77	Phase III III (65 days) Mar-June '78	Phase IV IV (129 days) July-Nov. '78
1	$WVG_{(v)}$	$WVG_{(v)}$	$WVG_{(1R)}$	$WVG_{(2R)}$
2	$WVG_{(v)}$	$WVG_{(v)}$	$WVG_{(1R)}$	$WVG_{(2R)}$
3	$WVG_{(v)}$	$WVG_{(v)}$	$WVG_{(1R)}$	$WVG_{(2R)}$
4	$ES\text{-}561_{(v)}$	$ES\text{-}561_{(1R)}$	$XE\text{-}340_{(2R)}$**	$XE\text{-}340_{(3R)}$*
5	$ES\text{-}561_{(v)}$	$ES\text{-}561_{(1R)}$	$IRA\text{-}904_{(v)}$	$IRA\text{-}904_{(1R)}$*
6	$XE\text{-}340_{(v)}$**	$XE\text{-}340_{(1R)}$**	$WVG_{(v)}$	$WVG_{(v)}$*
7	---	$HD\text{-}1030_{(v)}$	$HD\text{-}1030_{(1R)}$	$HD\text{-}1030_{(2R)}$
8	---	$HD\text{-}1030_{(v)}$	$HD\text{-}1030_{(1R)}$	$HD\text{-}1030_{(2R)}$
9	---	$HD\text{-}1030_{(v)}$	$HD\text{-}1030_{(1R)}$	$HD\text{-}1030_{(2R)}$
10	---	$LCK_{(v)}$	$A\text{-}162_{(v)}$	$WVG_{(1R)}$
11	---	$C\text{-}THM_{(v)}$	$WVG_{(v)}$	$WVG_{(v)}$
12	---	$ROW\ 0.8_{(V)}$	$HD\text{-}1030_{(v)}$	$HD\text{-}1030_{(v)}$
13	---	Sand	Sand	$HD\text{-}1030_{(v)}$
14	$XE\text{-}340_{(v)}$	$WVG_{(v)}$**	$LCK_{(v)}$	$WVG_{(v)}$
15	$EX\text{-}561_{(v)}$**	$ES\text{-}561_{(1R)}$**	$WVG_{(v)}$	$WVG_{(v)}$**

Empty Bed Contact Time:
[11.2 min @ 2 gpm/sf
[*2.2 min @ 10 gpm/sf

WVG	Bituminous Base Carbon - Westvaco
HD-1030	Lignite Base Carbon - ICI
LCK	Petroleum Base Carbon - Union Carbide
C-THM	Bituminous Base Carbon developed by Calgon for enhanced removal of trihalomethanes.
ROW 0.8	Extruded Peat Base Carbon - American Norit
ES-561	Weak Base Anion Exchange Resin - Diamond Shamrock
XE-340	Carbonaceous Resin - Rohm and Haas
IRA-904	Strong Base Anion Exchange Resin - Rohm and Haas
A-162	Strong Base Anion Exchange Resin - Diamond Shamrock

[**Adsorbents subjected to steaming
(v) Virgin adsorbent
(1R) Once regenerated
(2R) Twice regenerated
(3R) Thrice regenerated

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TABLE 2
PHYSICAL PROPERTIES OF THE ADSORBENTS (VIRGIN CONDITION)

Property	WVG	HD-1030	LCK	C-THM	ROW 0.8	ES-561	XE-340	IRA-904	A-162
Apparent Density ($\#/ft^3$)	27.5	26.2	31.2	41.5	26 - 28	40 - 45	37.4	41.8	46.4
Bed Density ($\#/ft^3$)	25	23	30	25 - 35	24	---	---	---	---
Surface Area (m^2/g)	1100	650	1000	500	900	---	400	65	50 - 100
Pore Volume (cc/g)	0.86	0.85	0.98	0.43	1.22	0.64	0.53	0.95	0.35
Iodine #	1060	544	950	590	1000	---	530	---	---
Molasses #	8.0	86	---	---	---	---	---	---	---
Phenol #	---	---	---	15 ± 4	6 - 8		---	---	---
Decolorizing Index	12.6	---	---	3.3	---	---	---	---	---
Moisture (%)	2.0	6	---	2 - 8	8	50 - 55	---	58	50 - 55
Ash (%)	8.5	15	5 - 8	---	5 - 8	---	0.5	0.5	---
Mesh	12 × 40	10 × 30	12 × 28	12 × 30	8 × 12	18 × 50	20 × 50	16 × 50	16 × 50
Effective Size (mm)	0.65	0.8 - 0.9	---	0.55 - 0.68	---	---	---	0.47	0.5

As in Phase I, the first module, Columns 1, 2, and 3, contained 9 ft of virgin Westvaco WVG. The second module, Columns 4, 5, and 6, also contained the same resins used in Phase I. The Diamond Shamrock ES-561, placed in the first two columns, was expected to adsorb high molecular weight organics, such as humic acids, and to release them when regenerated with a strong caustic. The third column of this series contained Ambersorb XE-340, the carbonaceous resin capable of adsorbing lower molecular weight substances such as the trihalomethanes. These materials were regenerated on site according to the manufacturer's instructions. Together it was expected that this second module would attain broad-spectrum organics removal with the first resin adsorbing precursor compounds and the second resin adsorbing the trihalomethanes themselves.

The third module consisted of Columns 7, 8, and 9 operated in series and each holding a 3-ft-deep bed of virgin ICI HD-1030, a lignite-base granular activated carbon. As with the first two modules, this module was designed as a deep-bed contactor with sampling points located at depths of 3, 6, and 9 ft of media.

The remaining six columns (10 through 15) were individual, parallel-flow units. Listed in consecutive order, these columns held 3-ft beds of the following adsorbents: 1) a virgin Union Carbide LCK, petroleum-base activated carbon; 2) a bituminous-base activated carbon developed by Calgon for enhanced removal of low molecular weight compounds, including trihalomethanes; 3) virgin American Norit ROW 0.8, an extruded peat-base activated carbon; 4) filter sand, to serve as a control; 5) virgin Westvaco WVG, periodically steamed to determine the role of biological growth on the removal of organic compounds; and 6) once-regenerated ES-561, the weak-base anion exchange resin, also periodically steamed.

Phase III

At the end of Phase II, the columns containing the Westvaco WVG and the ICI HD-1030 activated carbons were unloaded and the materials were shipped back to the manufacturers for regeneration. For Phase III, these regenerated materials were reloaded into Columns 1, 2, and 3 and Columns 7, 8, and 9, respectively. The Ambersorb XE-340 was again regenerated on site. A complete listing of the adsorbents that were included in Phase III is given in Table 1.

Phase III lasted from March 29, 1978, to June 2, 1978. All 15 columns were in operation. Columns 1, 2, and 3 were operated in series and contained once-regenerated Westvaco WVG; Columns 4, 5, and 6 were operated in series and contained Ambersorb XE-340 (twice regenerated), virgin Amberlite IRA-904 (preconditioned according to the manufacturer's instructions), and virgin Westvaco WVG; Columns 7, 8, and 9 were operated in series and contained once-regenerated ICI HD-1030; Column 10 contained Diamond Shamrock A-162, another strong-base anion exchange resin preconditioned according to manufacturer's instructions; Column 11 contained virgin Westvaco WVG; Column 12 contained virgin ICI HD-1030; Column 13 contained filter sand; Column 14 contained Union Carbide LCK; and Column 15 contained virgin

Westvaco WVG that was regularly backwashed but not steamed because it was used in a study of biological growth.

Because some loss of carbon (on a volume basis) occurred during the transfer and regeneration process, the flows through Columns 1, 2, 3, 11, and 15 were reduced to 0.35 gpm (1.75 gpm/ft^2) and the flows through Columns 7, 8, 9, and 12 were reduced to 0.34 gpm (1.70 gpm/ft^2) in order to maintain a constant empty-bed contact time of 11.2 minutes throughout the study. Columns 4, 5, 6, 10, 13, and 14 had approximately 36 in. of adsorbent, and flow was maintained at 0.4 gpm (2 gpm/ft^2).

Phase IV

At the end of Phase III, the columns containing Westvaco WVG and ICI HD-1030 were once again unloaded and the materials were shipped back to the manufacturers for a second regeneration. In Phase IV, the twice-regenerated materials were reloaded into Columns 1, 2, and 3 and Columns 7, 8, and 9, respectively. The third regeneration of Ambersorb XE-340 and the first regeneration of Amberlite IRA-904 were performed on site.

Phase IV, the final phase of the study, went from July 19, 1978, to November 25, 1978. The three series modules contained the same adsorbents utilized in Phase III. Column 10 contained once-regenerated Westvaco WVG; Column 11 contained virgin Westvaco WVG; Column 12 contained once-regenerated ICI HD-1030; Column 13 contained virgin ICI HD-1030; Column 14 contained virgin Westvaco WVG which was studied for biological growth but was not steamed; and Column 15 contained virgin Westvaco WVG which was studied for biological growth and was steamed on each sampling day.

Trihalomethane samples were taken at intermediate points for some of the adsorbents that were studied during Phase IV. These included the twice-regenerated Westvaco WVG (Column 1), the thrice-regenerated Ambersorb XE 340 (Column 4), the virgin Westvaco WVG (Column 6), the twice-regenerated ICI HD-1030 (Column 7), the once-regenerated Westvaco WVG (Column 10), and the virgin Westvaco WVG (Column 11). TOC analyses were not made of samples taken at intermediate points because of the amount of time required for performing this measurement.

Some loss in carbon (on a volume basis) was observed after the second regeneration process. As a result, the flows through the columns were reduced accordingly. During Phase IV the flow through Columns 1, 2, and 3 was reduced to 0.3 gpm (1.50 gpm/ft^2) while Columns 10 and 11 were operated at 0.32 gpm (1.60 gpm/ft^2). The flow through Columns 7, 8 and 9 was reduced to 0.30 gpm (1.50 gpm/ft^2) while Columns 12 and 13 were operated at 0.32 gpm (1.60 gpm/ft^2). Columns 14 and 15 contained approximately 36 in. of media and thus were operated at 0.40 gpm (2 gpm/ft^2).

Columns 4, 5, and 6 were operated at a much higher flow rate during Phase IV in order to exhaust the adsorbents more rapidly. This flow rate--2 gpm (10 gpm/ft^2)--produced an empty-bed contact time of approximately 2.24 minutes or one-fifth of the typical contact period used in the study.

ANALYSES

Trihalomethanes

The initial purpose of the pilot-plant study was to compare the capacities of granular activated carbon and polymeric adsorbents to remove trihalomethanes. Samples were collected from the pilot plant in glass bottles with Teflon seals and sent to Iowa State University for analysis by the liquid-liquid extraction technique during Phases I, II, and III, and part of Phase IV. The analytical chemists who performed these analyses cite the precision of this method as ± 100% for the range of 0 to 1 µg/l, ± 15% for the range of 1 to 10 µg/l, and ± 10% for values over 10 µg/l. For approximately the last two months of Phase IV the TTHM analyses were conducted in the laboratories of the University of Missouri at Columbia.

Total Organic Carbon

Early in the study it became evident that, in addition to TTHM, the removal of the total concentration of organic compounds present in drinking water would also be of great significance. Therefore, the parameter of Total Organic Carbon (TOC) was added to the list of analyses to be conducted. This addition was made possible by the decision of J. R. Popalisky, then the Director of the Kansas City water plant, to purchase a recently developed low-level TOC analyzer manufactured by Dohrmann-Envirotech to monitor plant treatment processes. This instrument, a Model DC-54 Low Level TOC Analyzer, was unique in its ability to detect purgeable and non-purgeable TOC at levels as low as 1 µg/l and 10 µg/l, respectively. The precision of this analysis is about ± 3%. Pilot-plant samples were analyzed for TOC by the EPA laboratory in Cincinnati during Phase I, at the Kansas City Water Treatment Plant Laboratory during Phases II and III, and at the laboratories of the University of Missouri-Columbia during Phase IV.

Threshold Odor Number

Threshold Odor Number (TON), a test that was carried out on a regular basis by the laboratory personnel of the Kansas City Water Treatment Plant, indicated how well each adsorbent removed odor-producing compounds from the water. Although a rather subjective test, TON--an aesthetic factor of particular importance to consumers--was another parameter used to judge the performance of the adsorbents.

Biological Growth

Throughout the study two columns containing either a granular activated carbon or a resin were equipped and instrumented so that the contents could be subjected to low-pressure steam at regular intervals. This was done in an effort to inhibit biological growth on the adsorbents. Other columns containing these same materials were operated normally without steaming. This was done in an effort to determine whether the accumulation of biological growth on the adsorption media was responsible, in part, for the observed removal of TTHM and TOC. It was recognized that the activated carbon might be partially regenerated and the resin degenerated (as a result

of loss of reactive amine groups) by this method. However, it was felt that these effects might not be so great as to obscure the results of this treatment. At the termination of each major phase of the project, samples were taken of each adsorbent and the quantity of biological growth was determined by dislodging organisms from the media in a consistent manner and then executing the Standard Plate Count Method as outlined in the 14th edition of Standard Methods for the Examination of Water and Wastewater.

Chemical Parameters

Tables listing the various chemicals added during the normal treatment process at the Kansas City Water Treatment Plant and their dosages were compiled for the day before sampling and the day of sampling. This information was collected for possible correlation between chemical addition and TTHM formation and appears in Appendix D.

REGENERATION OF RESIN ADSORBENTS

Diamond Shamrock ES-561

Regeneration was performed at a flow rate of 0.5 gpm/ft^3 of resin. A base solution of 3% NaOH (at a total dosage of 2 lb/ft^3 of resin) was applied, followed by a water wash. The rinse rate was 1 to 2 gpm/ft^3, until about 40 gal/ft^3 had been applied.

Amberlite IRA-904

Pretreatment--

This step was performed for the removal of residual organics prior to use for water treatment. The steps for the regeneration of this material were followed, repeating the cycle three times.

Regeneration--

Regeneration was performed at a flow rate of 0.25 gpm/ft^3 of resin. A base solution of 3% NaOH (at a total dosage of 2 lb/ft^3 of resin) was applied and was followed by a 10% solution of NaCl (at a total dosage of 15 lb/ft^3 of resin).

Ambersorb XE-340

This material was regenerated in place with low pressure steam. Approximately 1.5 bed volumes of water were converted to steam and passed through the bed in the down-flow mode. The system was pressurized at about 12 psig. The steaming procedure took place over a period of 30-45 min. Steam temperatures were maintained within the column and the condensate was collected outside the column.

SECTION 6

RESULTS AND DISCUSSION

OVERVIEW

Throughout the following discussion, reference will be made to tables that list the percentage of the influent of total trihalomethanes (TTHM) and total organic carbon (TOC) removed by each adsorbent. These values were calculated on a mass basis and were derived by taking the average for consecutive sampling days and multiplying by the flow through each bed during that period. Calculations for the single, parallel flow columns were made using the pilot plant influent data. For units comprised of three columns in series, the results were determined both in terms of the actual percentage removal achieved by each individual bed and the cumulative percentage removal through the unit. The cumulative percent removal values are based on the influent to the unit and not on the influent to each individual column.

TTHM and TOC removals on a weight basis were determined at the conclusion of each run and were derived by taking a ratio between the total mass of either TTHM or TOC that was adsorbed and the total weight of adsorbent in each bed. Since not all of the adsorbents were exhausted at the conclusion of each phase, these values were calculated principally to compare the quantity of adsorbate removed on a weight basis in addition to a volume basis. These values are not to be taken as absolute adsorption capacities, but merely as a relative condition that existed at the end of each phase.

PHASE I

Total Trihalomethane (TTHM)

The influent concentration of TTHM ranged from 4 to 83 µg/l during the 133-day period of this study. Table 3 lists the percentage of the influent quantity of TTHM that was removed by each adsorbent during Phase I. It also shows the mg of TTHM adsorbed per gram of adsorbent and the number of bacterial colonies recovered per gram of adsorbent.

Westvaco WVG

For the first 111 days of Phase I, a 9-ft bed of Westvaco WVG removed 99% of the influent TTHM, with 80% of this quantity being adsorbed by the first 3-ft bed, an additional 19% by the second 3-ft bed, and less than 1% by the third 3-ft bed. Over the entire 133-day period, 99% of the influent quantity of TTHM was removed with 70% having been adsorbed by the first bed,

TABLE 3
PERCENTAGE OF TTHM REMOVED DURING PHASE I

Column Number	Adsorbent	111-day Period		133-day Period		TTHM Removal, mg/gram of Adsorbent	SPC Colonies per gram of Adsorbent
		Cumulative % TTHM Removal	Column % TTHM Removal	Cumulative % TTHM Removal	Column % TTHM Removal		
1	WVG	80%	80%	70%	70%	1.06	89,000
2	WVG	99%	19%	98%	28%	0.43	1,200
3	WVG	99%	1%	99%	1%	0.01	300
4	ES-561	-1%	-1%	-8%	-8%	-0.13	450
5	ES-561	+3%	+4%	-7%	+1%	-0.12	400
6	XE-340	---	98%	---	98%	1.07	900
14	WVG (Steamed)	---	92%	---	87%	1.32	5,800
15	ES-561 (Steamed)	---	-2%	---	-9%	-0.15	300

28% by the second, and 1% by the last bed in the series. Comparing these two sets of data shows that after 133 days of operation, the first bed was nearly exhausted and the adsorptive capacity of the second bed began to be utilized. This phenomenon is illustrated in Figures 2 and 3.

In Figure 2, chloroform (which comprised 85% of the total quantity of TTHM in the influent) began to appear in the effluent from Column 1 after about one month of operation. At the end of Phase I, Column 1 was removing only a small fraction of the influent chloroform. Figure 3 shows that nearly all of the chloroform that passed through Column 1 was retained by Column 2. The effluent from Column 2 always contained less than 5 µg/l of trihalomethanes. Data for Column 3 were not plotted because little TTHM was present in the influent to this bed and essentially all of it was removed.

Column 14, which contained Westvaco WVG that was periodically steamed, achieved a higher degree of TTHM removal than a comparable column that had not been steamed. After 111 days, the steamed bed had removed 92% of the influent TTHM whereas Column 1 had removed only 80% of the total. After 133 days of operation, Column 14 had removed 87% while Column 1 had removed 70% of the influent TTHM. Occasional steaming appeared to enhance the activated carbon's ability to adsorb TTHM by 24%.

Figure 4 shows the removal of chloroform by the Westvaco WVG Column 14 during Phase I. For the first 78 days of operation only a few µg/l of chloroform appeared in the effluent. After that time, breakthrough began to occur but was not complete at the end of 133 days of operation. At least 66% of the influent chloroform was still being removed after 133 days.

Diamond Shamrock ES-561

The data in Table 3 indicate that this weak base anion exchange resin did not remove TTHM. Instead, it seemed to enhance their formation. A plot of the influent and effluent concentrations of chloroform for Column 4, given in Figure 5, indicated that some TTHM formation may have taken place during the period of 111 to 118 days. Similar results were obtained for Columns 5 and 15. Steaming did not appear to improve TTHM removal by the resin or to make it worse.

Rohm and Haas Ambersorb XE-340

The carbonaceous resin adsorbent, Ambersorb XE-340, exhibited the highest removal of TTHM in Phase I. After 111 days of operation, the material in Column 6 had removed 92% of the TTHM that was present in the effluent of Column 5, and 87% after 133 days of operation. These levels are 15% greater than those attained by Westvaco WVG for the same periods. Because TTHM in the effluent of Column 5 was approximately the same as that in the influent of the pilot plant, it is possible to compare the performance of Column 6 to that of the rest of the single columns with respect to TTHM removals.

Figure 5 illustrates the affinity of chloroform for the Ambersorb XE-340. Throughout the 133 days of Phase I, the effluent of Column 6 contained less than 3 µg/l of chloroform and never exhibited signs of becoming exhausted.

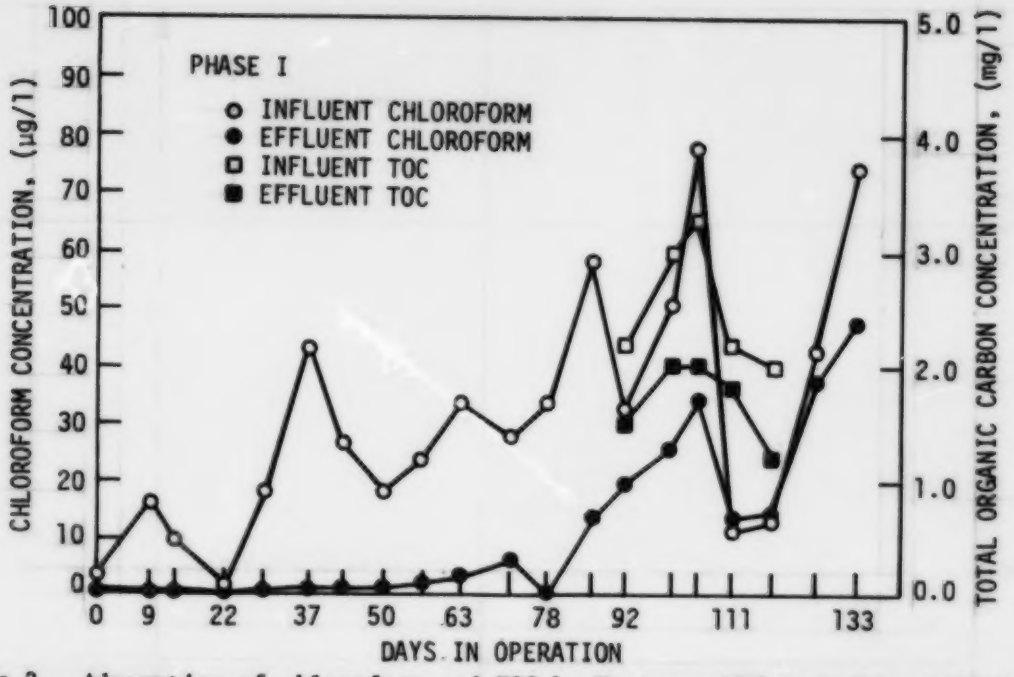
PHASE I
INFLUENT CHLOROFORM
EFFLUENT CHLOROFORM
INFLUENT TOC
EFFLUENT TOC
CHLOROFORM CONCENTRATION, (µg/l)
TOTAL ORGANIC CARBON CONCENTRATION, (mg/l)
DAYS IN OPERATION
0 9 22 37 50 63 78 92 111 133
0 10 20 30 40 50 60 70 80 90 100
0.0 1.0 2.0 3.0 4.0 5.0

Figure 2. Adsorption of chloroform and TOC by Westvaco WVG granular activated carbon (Column 1).

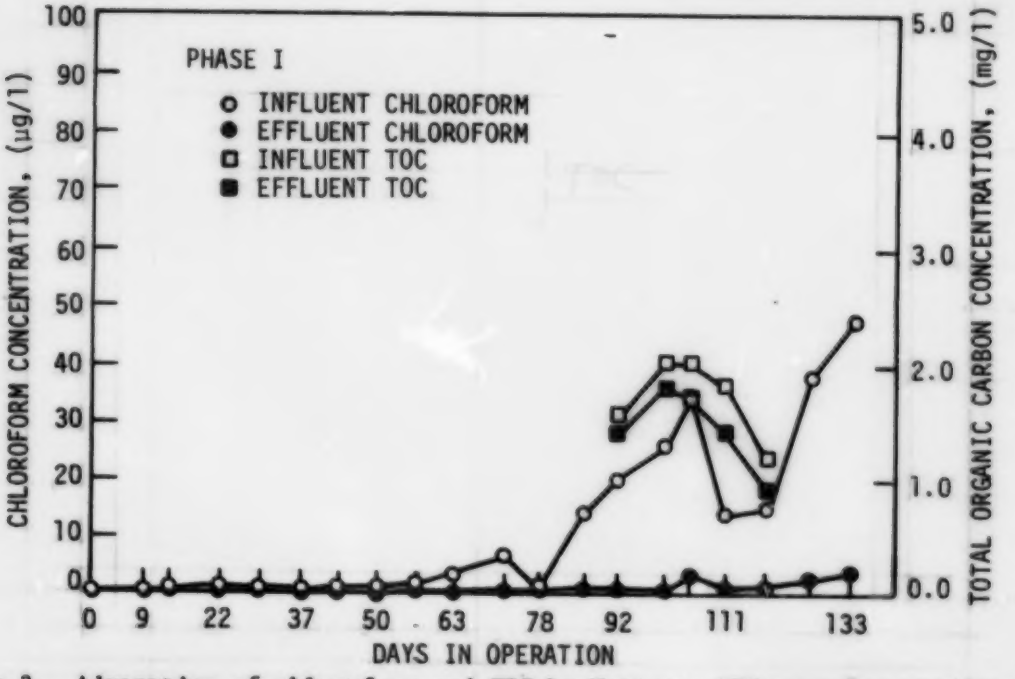
PHASE I
INFLUENT CHLOROFORM
EFFLUENT CHLOROFORM
INFLUENT TOC
EFFLUENT TOC
CHLOROFORM CONCENTRATION, (µg/l)
TOTAL ORGANIC CARBON CONCENTRATION, (mg/l)
DAYS IN OPERATION
0 9 22 37 50 63 78 92 111 133
0 10 20 30 40 50 60 70 80 90 100
0.0 1.0 2.0 3.0 4.0 5.0

Figure 3. Adsorption of chloroform and TOC by Westvaco WVG granular activated carbon (Column 2).

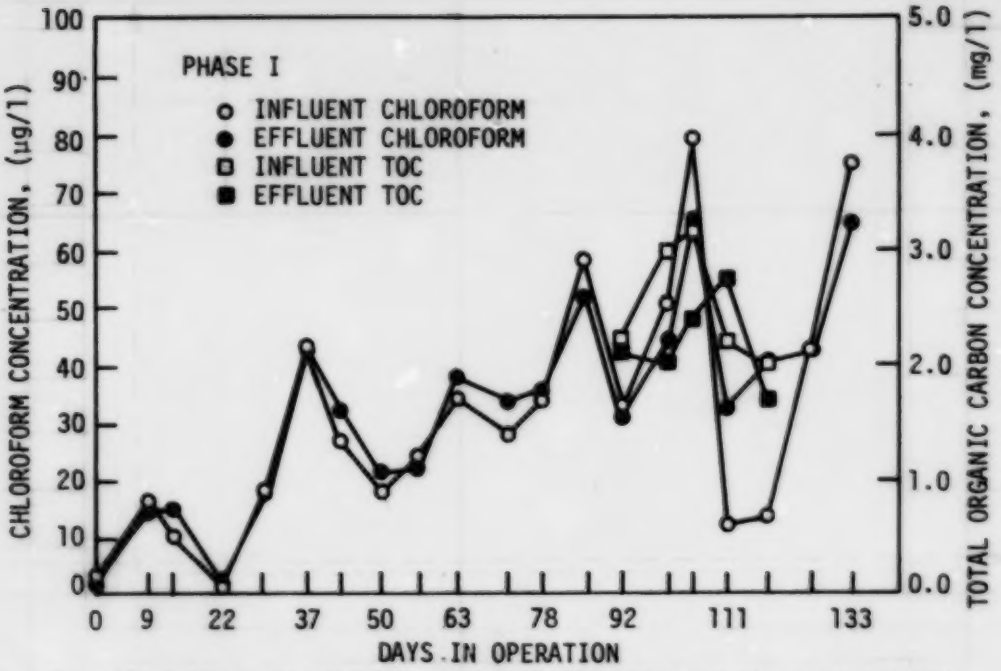
PHASE I
INFLUENT CHLOROFORM
EFFLUENT CHLOROFORM
INFLUENT TOC
EFFLUENT TOC
CHLOROFORM CONCENTRATION, (µg/1)
TOTAL ORGANIC CARBON CONCENTRATION, (mg/1)
DAYS IN OPERATION
0 9 22 37 50 63 78 92 111 133
0 10 20 30 40 50 60 70 80 90 100
0.0 1.0 2.0 3.0 4.0 5.0

Figure 4. Adsorption of chloroform and TOC by Diamond Shamrock ES-561 weak base anion exchange resin (Column 4).

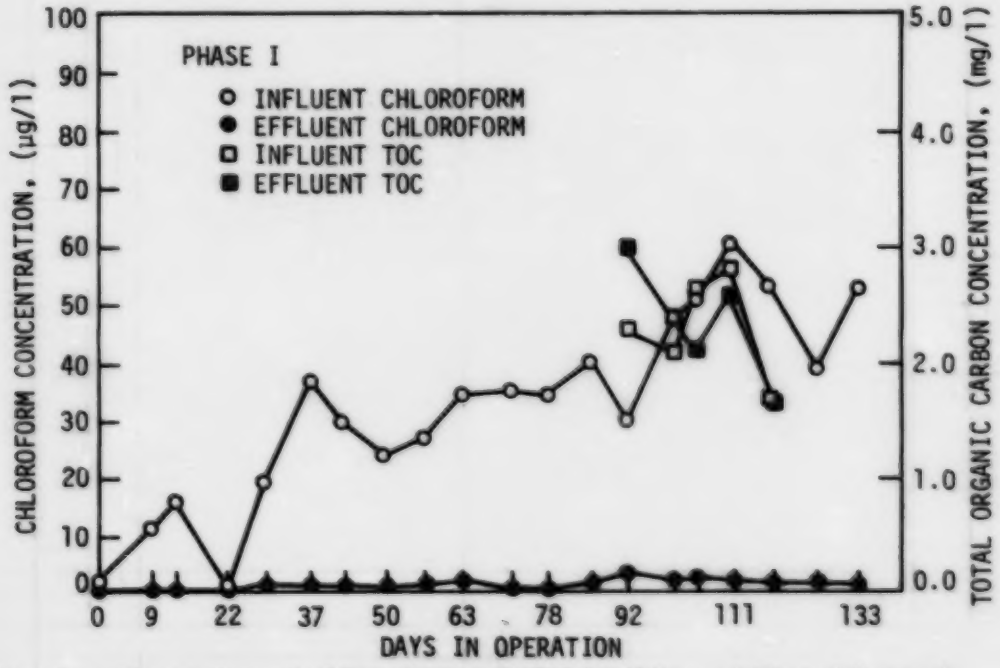
PHASE I
INFLUENT CHLOROFORM
EFFLUENT CHLOROFORM
INFLUENT TOC
EFFLUENT TOC
CHLOROFORM CONCENTRATION, (µg/1)
TOTAL ORGANIC CARBON CONCENTRATION, (mg/1)
DAYS IN OPERATION
0 9 22 37 50 63 78 92 111 133
0 10 20 30 40 50 60 70 80 90 100
0.0 1.0 2.0 3.0 4.0 5.0

Figure 5. Adsorption of chloroform and TOC by Rohm and Haas Ambersorb XE-340 carbonaceous resin (Column 6).

Total Organic Carbon (TOC) Removal

Although the proper instrumentation to conduct TOC analysis did not become available on a regular basis until the beginning of Phase II, a few weeks of samples were analyzed at the EPA Municipal Environmental Research Laboratory in Cincinnati, Ohio. Some of this information is presented in Figures 2 through 6. The influent level of TOC ranged from 2 to 3 mg/l during the sampling period.

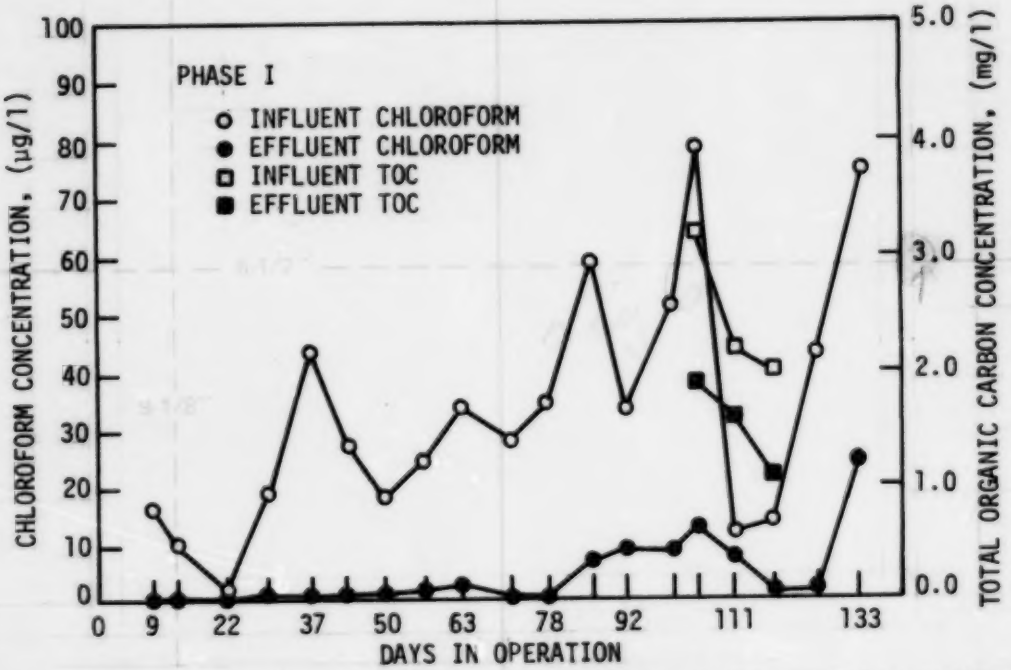

Figure 6. Adsorption of chloroform and TOC by Westvaco WVG granular activated carbon periodically steamed (Column 14).

Westvaco WVG

The three beds of Westvaco WVG in series were observed to remove from 50 to 60% of the influent TOC. From 30 to 40% of the influent TOC was removed by the first bed in the series, an additional 5 to 15% by the second bed, and another 10 to 20% by the last bed. The single bed that was occasionally steamed achieved about 10% higher removals of TOC than the unsteamed bed. Effluent samples taken directly after steaming indicated that organic material had been displaced from the resin as a result of the steaming.

Diamond Shamrock ES-561

Column 4, the first bed in the resin series, erratically removed from 5 to 30% of the influent TOC. Column 5 either removed no additional TOC or seemed to contribute organic material equivalent to 4 to 6% of the influent values. Steaming this resin did not increase TOC removals. Once again, higher levels of organic materials were found in the effluent sampled immediately after steaming.

Rohm and Haas Ambersorb XE-340

The removal of TOC by this adsorbent was inconsistent. At times it appeared to adsorb from 10 to 30% of the TOC present in the effluent of Column 5, while on other occasions it appeared to contribute TOC equivalent to 18 to 36% of the quantity present in the influent of the pilot plant.

Threshold Odor Number Reduction

Sampling for TON occurred during the latter half of Phase I. Influent values ranged from 1 to 4 with an average of between 2 and 3. Odors were usually characterized as musty. The results of the TON analyses are presented in Table C-1 of Appendix C.

Westvaco WVG

On days when the influent to the pilot plant had a TON of 3 or 4, the activated carbon was able to produce an effluent with a TON of 1 but it usually required 6 to 9 ft of the adsorbent to do so. When the influent had a TON of 2, a 3-ft deep bed of activated carbon generally reduced this value to 1. On some sampling days, the odor appeared to be intensified slightly. The generally musty odor characteristic of the influent water was frequently described as a chemical or chemical-hydrocarbon odor after passing through the carbon.

The steamed carbon bed rarely reduced the TON and often intensified it. This behavior could not be directly correlated with samples that were taken shortly after the media had been steamed. As with the activated carbon that was not steamed, the character of the effluent from the steamed bed was termed as chemical or chemical-hydrocarbon in nature.

Diamond Shamrock ES-561

Odorous compounds usually either were not removed or were intensified after contact with the Diamond Shamrock ES-561. The character of the TON of the effluent of Columns 4 and 5 was described as being chemical, chemical-hydrocarbon, chemical-medicinal, aromatic, and balsamy-sweet in nature. This would indicated that a wide variety of odor-producing organic compounds might be present. The effluent of the resin that was steamed exhibited these same odors.

Rohm and Haas Ambersorb XE-340

During Phase 1, the carbonaceous resins exhibited good odor-removing capability, better than that observed for an equivalent volume of activated carbon. The effluent of Column 5, which ranged in TON value from 2 to 8 with an average of about 3, was usually reduced to a value of 1. When the TON in the influent to Column 6 rose to 6 or 8, the TON of the effluent was 2. Unlike the other adsorbents, Ambersorb XE-340 did not seem to alter the odor characteristic of the water. The effluent stream of Column 6 was most often characterized as musty.

Biological Growth

The results of the bacterial analyses that were performed on media samples of each adsorbent at the conclusion of Phase I are presented in Table 4. As expected, a higher number of colonies were recovered from the activated carbon than from the resins. The number of colonies found on the three activated carbon columns in series seemed to parallel the organics removal by these beds. That is, the first column in the series which had adsorbed the largest quantity of TTHM and TOC also cultured the highest population of microorganisms.

Microbial growth was diminished on the adsorbents that had been steamed. This effect was more evident on the activated carbon than on the resin adsorbents.

PHASE II

Trihalomethane Removal

The influent concentration of TTHM ranged from 5 to 211 µg/l during this period. Table 4 lists the quantity of TTHM and TOC that was removed by each adsorbent during Phase II.

Westvaco WVG

After 111 days of operation, a 9-ft bed of Westvaco WVG granular activated carbon had removed 99% of the influent TTHM, with 80% of this quantity being adsorbed by the first 3-ft bed, an additional 18% by the second 3-ft bed, and approximately 1% by the final bed in the series. Column 14, which contained the Westvaco WVG that had been steamed, removed 92% of the total influent TTHM during the same period. Once again, occasional steaming appeared to enhance the activated carbon's ability to adsorb TTHM by increasing the removal of these compounds by about 15%. This agrees very well with the results obtained in Phase I.

Figures 7 and 8 illustrate the removal of chloroform by Columns 1 and 14. Chloroform, which accounted for 88% of the total TTHM present in the influent during Phase II, did not appear in the effluent of Column 1 to any significant degree until after 34 days of operation. Beyond this point, chloroform continued to increase in the effluent of this column and almost

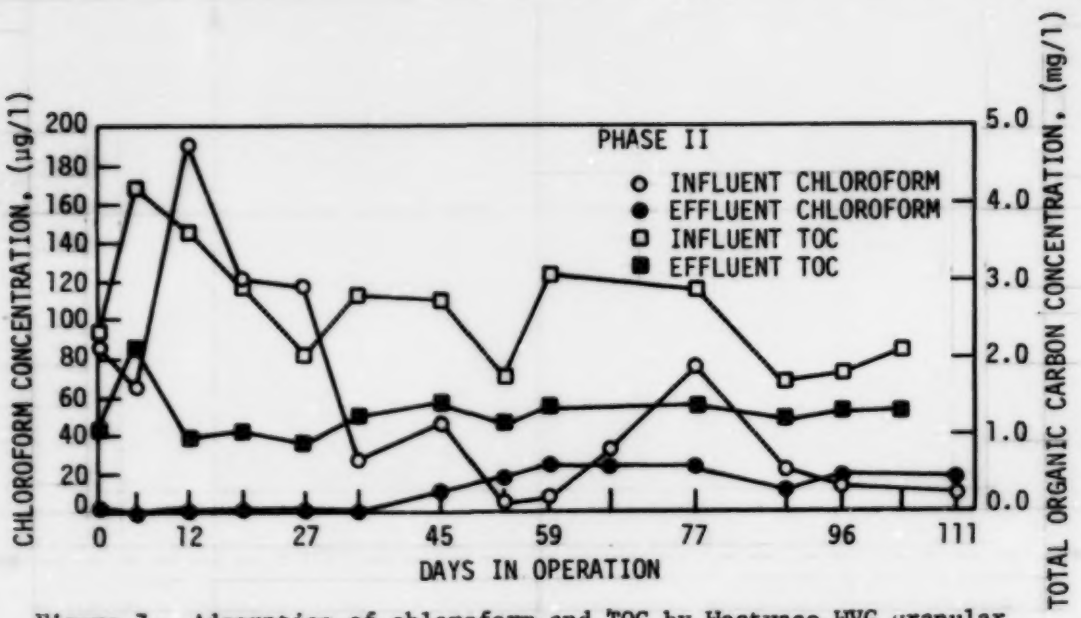

Figure 7. Adsorption of chloroform and TOC by Westvaco WVG granular activated carbon (Column 1).

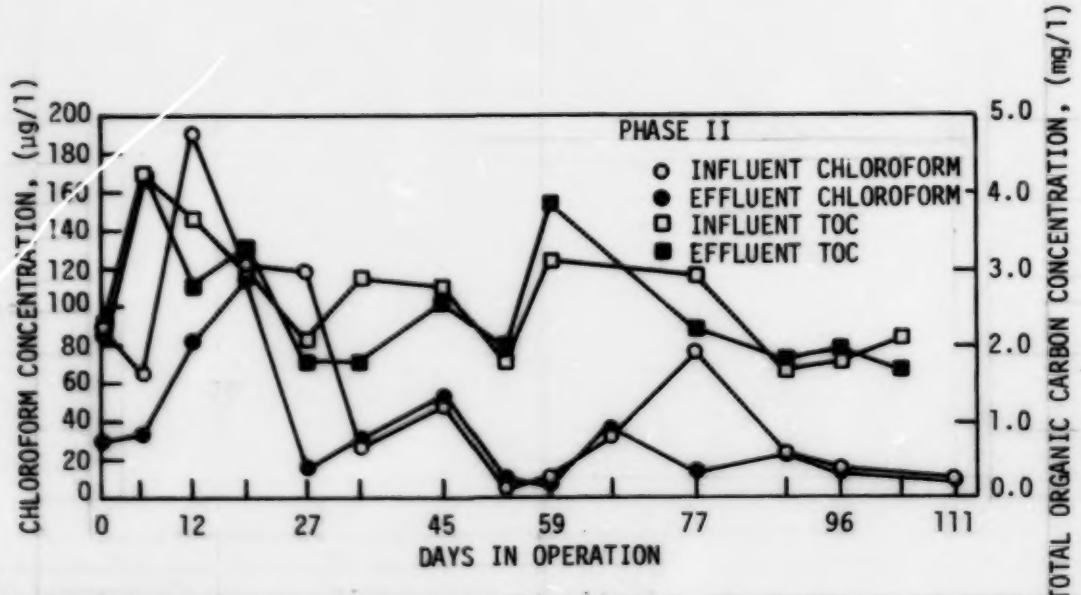

Figure 8. Adsorption of chloroform and TOC by Diamond Shamrock ES-561 weak base anion exchange resin (Column 4).

to reach a steady-state condition; that is, chloroform seemed to desorb from the column when the influent concentration dropped to a low value.

The Westvaco WVG, ICI HD-1030, Union Carbide LCK, and Calgon's carbon for TTHM exhibited comparable (80-85%) column removal of TTHM. Only the American Norit Row 0.8 achieved lower removal (68%).

Diamond Shamrock ES-561

Conflicting results were obtained for this adsorbent in terms of TTHM removal. For Column 4, the first of two anion exchange resin beds in series, 29% removal was observed while the bed immediately following it seemed to return half of this amount back into the effluent stream. Figure 9 shows a plot of chloroform removal and TOC removal by Column 4 during Phase II. Little TTHM removal occurred after 34 days.

Rohm and Haas XE-340

As expected, XE-340 was an effective adsorbent for TTHM, removing 90% of the TTHM present in the effluent of Column 5. While the carbonaceous resin was not as effective in Phase II as it was in Phase I where 98% of the incoming TTHM was removed, Figure 10 shows that the effluent chloroform concentration from Column 6 was rather stable and did not rise and fall with fluctuations in TTHM influent concentrations. The calculated 1.17 mg of TTHM adsorbed per gram of this adsorbent during Phase II is low in comparison to the ultimate capacity of this adsorbent for TTHM since the resin was not exhausted.

ICI HD-1030

After 111 days of operation, a 9-ft bed of ICI HD-1030 granular activated carbon removed 99% of the influent TTHM. The ICI HD-1030 removals shown in Table 4 were very close to those achieved by the Westvaco WVG.

Figure 11 illustrates the removal of chloroform and TOC by the first 3-ft bed of the ICI HD-1030 series, Column 7. Chloroform was first detected in the effluent of Column 7 after 19 days of operation.

Union Carbide LCK

A 3-ft bed of this granular activated carbon removed 82% of the TTHM present in the influent of the pilot plant. This performance was comparable to that of the Westvaco WVG and the ICI HD-1030 activated carbons. On a weight basis the TTHM removal by this carbon was determined to be 1.52 mg/g, about 20% lower than that of the other carbons. This is because of the greater density of the Union Carbide LCK as indicated in Table 2. Figure 12 shows a plot of chloroform and TOC removal by the Union Carbode LCK.

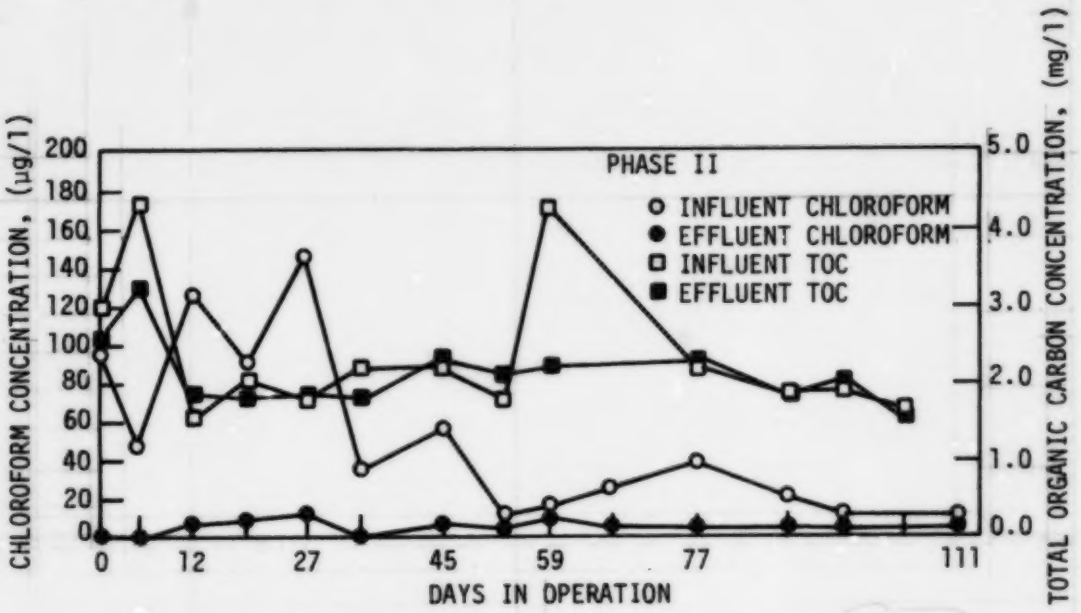

Figure 9. Adsorption of chloroform and TOC by Rohm and Haas Ambersorb XE-340 carbonaceous resin (Column 6).

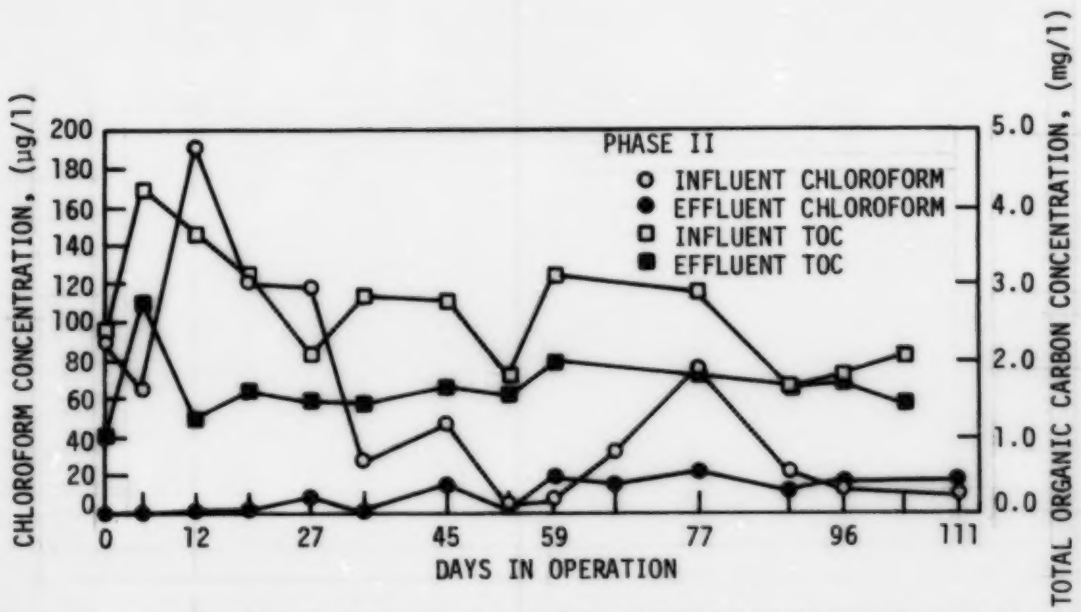

Figure 10. Adsorption of chloroform and TOC by ICI HD 1030 granular activated carbon (Column 7).

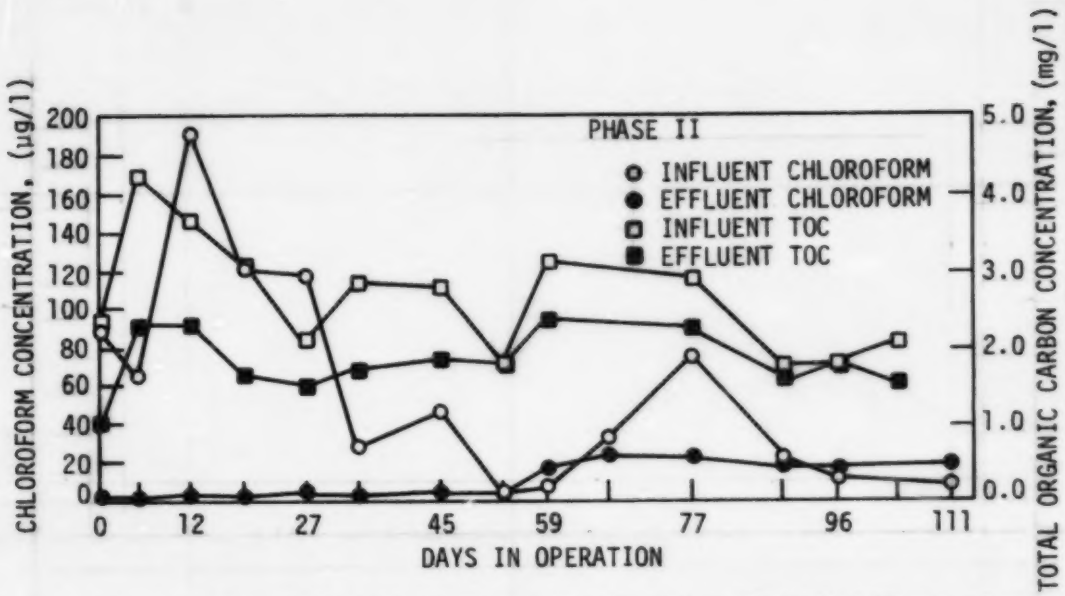

Figure 11. Adsorption of chloroform and TOC by Union Carbide LCK granular activated carbon (Column 10).

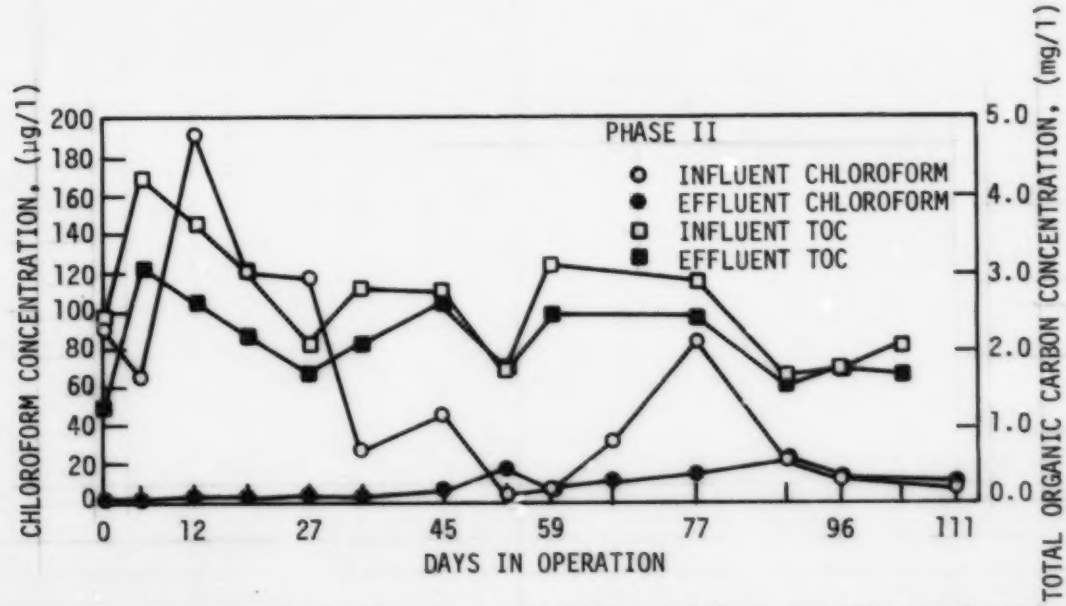

Figure 12. Adsorption of chloroform and TOC by a Calgon granular activated carbon developed for enhanced removal of Trihalomethane (Column 11).

Calgon's Carbon for TTHM

A 3-ft bed of a new granular activated carbon developed by Calgon for enhanced TTHM removal adsorbed 85% of the TTHM in the influent of the pilot plant. This performance appeared to be slightly better than that of the other activated carbons that were studied. However, on a weight basis, TTHM adsorption was only 1.28 mg/g or about 30% lower than that of the other activated carbons.

Figure 13 illustrates the removal of chloroform and TOC by Calgon's carbon for TTHM. This adsorbent was very similar to the other activated carbons studied in that a low level of chloroform present in the effluent shortly after start-up remained at a low level for approximately a month before displaying signs of gradual breakthrough. This activated carbon did not appear to desorb chloroform as readily as some of the other carbons when it was subjected to high, followed by low, influent levels of chloroform.

American Norit Row 0.8

This activated carbon, which is manufactured from peat and sold as an extruded form rather than the typical granular shape, removed the smallest quantity of TTHM during Phase II. A 68% removal of TTHM was achieved by a 3-ft bed of this adsorbent, although, on a weight basis, it adsorbed about 1.61 mg/g. Figure 14 shows that signs of breakthrough were evident after 34 days of operation and that effluent concentration levels continued to increase after this time. This adsorbent obviously desorbed chloroform during periods of low influent concentrations.

Filter Sand

Filter sand, was included in the study as a control. Figure 15 is a plot of the removal of chloroform and TOC by filter sand. It indicates that, if removal did occur, it did so in surges rather than as a continuous process. This would tend to suggest that, in this case, the calculated removal was not genuine and may have been the result of two inaccurate data points. If actual removal of TTHM was occurring, it would be expected that some degree of removal should be indicated over the entire experimental period rather than at two distinctly separate points in time.

Total Organic Carbon Removal

The influent TOC ranged from 2 to 4 mg/l during Phase II, with an average value of about 3 mg/l. Table 4 gives the percentage of influent TOC removal by each adsorbent.

Westvaco WVG

The three activated carbon beds in series removed 75% of the influent TOC. About two-thirds of the total removal, or 51% was accomplished by the first bed; while an additional 15% was removed by the second bed and another 9% by the final bed in the series. Column 14 (steamed) exhibited a slightly higher removal than Column 1 with 56% of the influent TOC being removed.

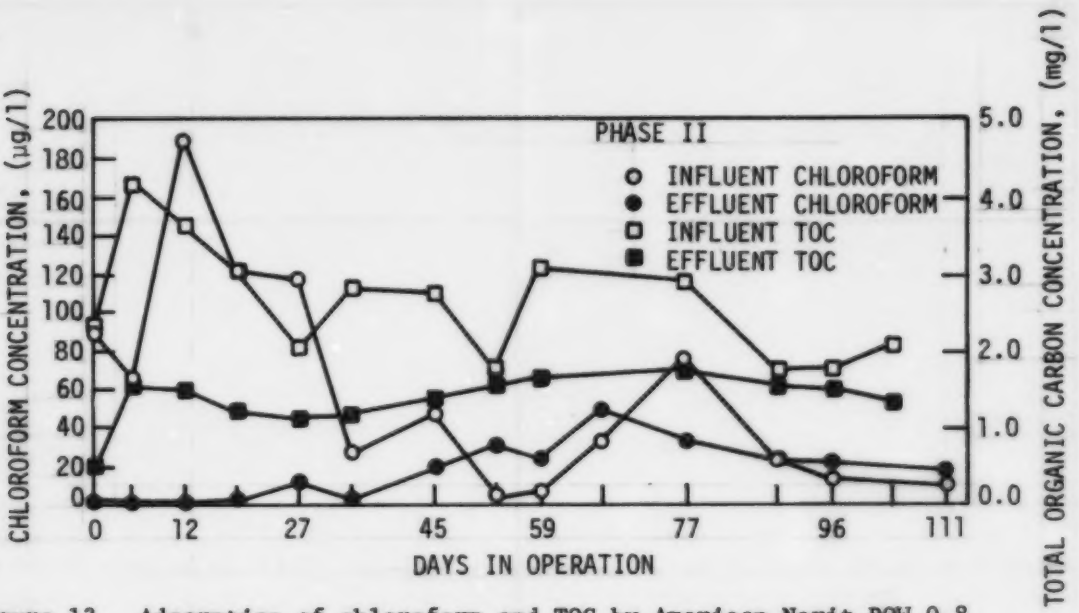

Figure 13. Adsorption of chloroform and TOC by American Norit ROW 0.8 activated carbon (Column 12).

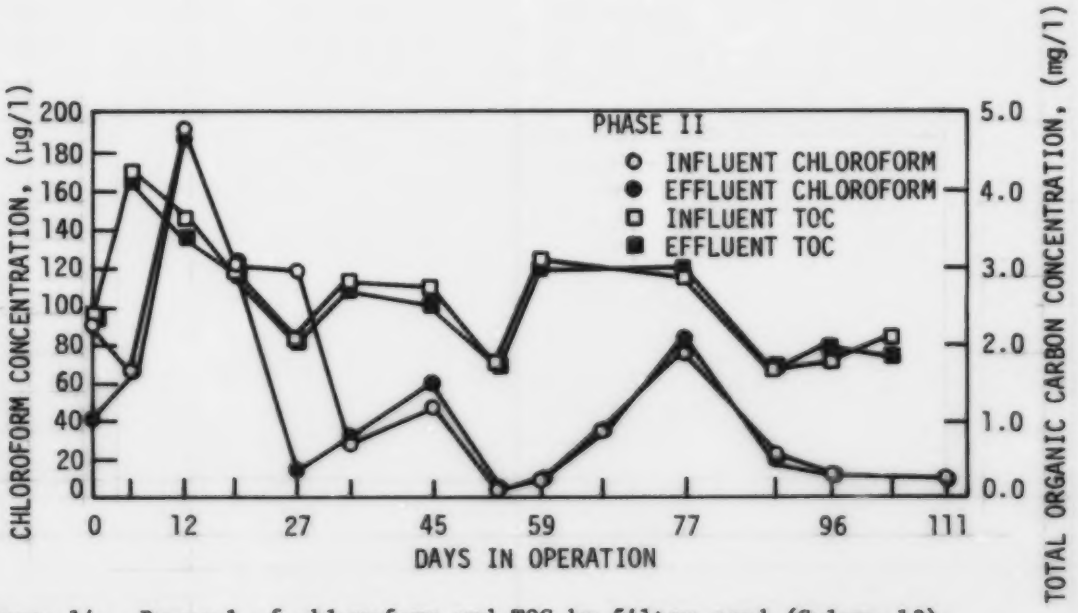

Figure 14. Removal of chloroform and TOC by filter sand (Column 13).

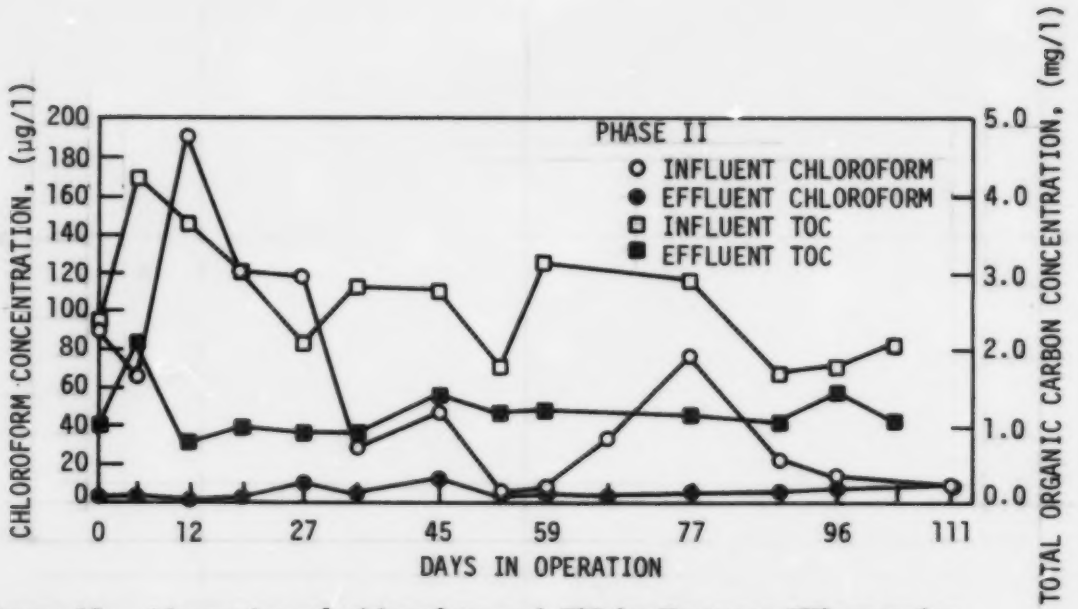

Figure 15. Adsorption of chloroform and TOC by Westvaco WVG granular activated carbon - periodically steamed (Column 14).

Westvaco WVG removed more TOC than any of the other adsorbents included in the study. At the close of Phase II, Column 1 had adsorbed 41.4 mg of TOC per gram of carbon while Column 14 had adsorbed 45.2 mg of TOC per gram of carbon.

Figures 7 and 8 show that the removal of TOC by Column 1 and Column 14 were nearly identical throughout Phase II. The curves representing the effluent concentration of TOC from each of these columns are fairly horizontal, indicating that there was a constant fraction of organic compounds present in the influent which could not be removed by the activated carbon. The implication is that the treated Missouri River water, at least occasionally, contains a fraction of poorly adsorbable organic solutes that will penetrate even fresh beds of granular activated carbon.

Diamond Shamrock ES-561

A 3-ft bed of the Diamond Shamrock ES-561 removed from 7 to 13% of the influent TOC. This adsorbent, which was expected to remove high molecular weight compounds such as humic materials, did not function well in this respect, possibly because of the high pH of the influent water. The bed of this adsorbent that was steamed achieved only the same removal of TOC as the bed that was not steamed.

Figure 9 shows little removal of TOC by Diamond Shamrock ES-561 in Column 4 during Phase II. On occasion, this adsorbent appeared to contribute organic material to the effluent stream rather than remove it.

Rohm and Haas Ambersorb XE-340

The 3-ft bed of Ambersorb XE-340 removed approximately 11% of the TOC present in the effluent of Column 5. As can be seen from Figure 10, essentially no TOC removal was achieved during most of the experimental period.

ICI HD-1030

Because ICI HD-1030 was not as effective in removing TOC as the Westvaco WVG activated carbon, a 9-ft bed of HD-1030 was required to produce the same TOC removal as a 3-ft bed of Westvaco WVG. A 37% removal was achieved by the first 3-ft bed; an additional 12% was contributed by the second bed, and about 5% of the influent TOC was removed by the third bed in the series. However, only the Row 0.8 and the WVG removed more TOC than the HD-1030. At the end of Phase II, Column 7 had adsorbed 30.5 mg of TOC per gram of carbon as compared to 41.4 mg/g for the WVG and 38.9 mg/g for the Row 0.8.

Figure 11 shows removal of TOC by ICI HD-1030 in Column 7 during Phase II. This figure is very similar in appearance to that for Column 1 with respect to the nearly constant residual concentration of TOC in the effluent.

Union Carbide LCK

A 3-ft bed of Union Carbide LCK granular activated carbon removed 30% of the TOC present in the influent (Figure 12). This was less than all of

the other activated carbons except for the new activated carbon developed by Calgon for enhanced TTHM removal. TOC removal for this adsorbent was calculated to be 20 mg/g at the conclusion of Phase II.

Calgon's Carbon for TTHM

A 3-ft bed of Calgon's new granular activated carbon developed for enhanced removal of TTHM removed only 19% of the TOC present in the influent (Figure 13). This was the poorest TOC removal exhibited by any of the activated carbons studied. Since it was denser than all of the other carbons, this carbon also exhibited the lowest TOC removal on a weight basis, adsorbing only 10.1 mg of TOC per gram of carbon.

American Norit Row 0.8

This activated carbon proved to be nearly equivalent to Westvaco WVG in capability for removing TOC. About 45% of the TOC in the influent was removed by the 3-ft bed of this adsorbent. At the end of Phase II, about 40 mg of the TOC was removed per gram of adsorbent. Figure 14 shows the TOC removal by American Norit Row 0.8 during Phase II. The effluent TOC curve shows an almost immediate passage of "poorly adsorbable" TOC. Thereafter, the removal curve showed a smooth and regular upward trend, virtually "buffering" changes in influent TOC concentration.

Filter Sand

From the curves presented in Figure 15, it appears that little to no TOC removal occurred on the sand. The calculations indicate that 2% of the influent TOC was removed by the sand. It is likely that the small differences observed between the influent and effluent TOC concentrations for this column are within the precision of this measurement so that no actual removal occurred.

Threshold Odor Number (TON) Removal

Influent TON values ranged from 1 to 4 and were usually characterized as having a musty odor. The average influent value of TON was between 2 and 3, making assessments of TON reduction extremely tenuous.

Westvaco WVG

Columns 1 through 3 did not consistently reduce the odor of the influent water. Usually influent values of 2 and 3 were reduced to 1 and 2, respectively, but odor reduction did not always improve with increasing bed depth. Sometimes odors seemed to be enhanced after contact with the activated carbon. The characteristic musty odor of the influent water appeared to change to a chemical, chemical-hydrocarbon, or earthy odor after contact with a 3-ft bed of Westvaco WVG. Steaming of the Westvaco WVG appeared to result in increased TON values. The TON of the effluent from Westvaco WVG (steamed) in Column 14 was generally described as having the characteristic musty odor, like that of the influent, and not a chemical or chemical-hydrocarbon odor.

Diamond Shamrock ES-561

The weak-base anion exchange resin had little effect on the magnitude of the TON of the influent water during Phase II, nor did steaming result in increased TON as it did in Phase I.

Rohm and Haas Ambersorb XE-340

In Phase II, the Ambersorb XE-340 did not reduce TON as well as it had in Phase I. "Chemical," "aromatic," and "disagreeable" were some of the terms used to describe the effluent from Column 6.

ICI HD-1030

As was the case with the Westvaco WVG the ICI HD-1030 did not appear to reduce odor effectively.

Union Carbide LCK

TON was only slightly reduced after contact with this adsorbent, and the Union Carbide LCK column effluent was characteristically chemical or chemical-hydrocarbon in nature.

Calgon's Carbon for TTHM

The performance of this adsorbent in reducing odors was variable. The column effluent had a characteristic chemical or chemical-hydrocarbon odor.

American Norit ROW 0.8

TON did not appear to be reduced after contact with this adsorbent, and sometimes it was increased.

Filter Sand

As expected, filter sand did not seem to reduce or increase TON dramatically. The data indicated that it did, however, tend to change the musty odor of the influent water to a slightly more chemical or aromatic odor.

Biological Growth

The results of the bacterial analyses performed on samples of each adsorbent at the conclusion of Phase II are presented in Table 4. Unlike the results obtained from Phase I, the numbers of microorganisms present on the adsorbents were generally low and could not be correlated with the quantity of organic material adsorbed by each column. As a result, trends which were observed at the end of Phase I (in August) were not observed at the end of Phase II (in December). For instance, in Phase II it appeared that more growth occurred on the weak-base anion exchange resin than on the carbonaceous resin but just the reverse occurred in Phase I. Because the results of Phase II were inconsistent with those of Phase I, additional work was performed to try to resolve these differences.

TABLE 4
PERCENTAGE OF TTHM AND TOC REMOVED DURING PHASE II

Column	Adsorbent	TTHM		mg TTHM Adsorbed per gram	TOC		mg TOC Adsorbed per gram	SPC Colonies per gram of Adsorbent*
		Cumulative Removal	Column Removal		Cumulative Removal	Column Removal		
1	WVG	80%	80%	1.78	51%	51%	41.4	520
2	WVG	98%	18%	0.42	66%	15%	12.5	1,300
3	WVG	99%	1%	0.01	75%	9%	6.7	1,830
4	ES-561 (1R)	29%	29%	0.73	7%	7%	6.0	9,500
5	ES-561 (1R)	14%	-15%	-0.40	20%	13%	3.5	5,650
6	XE-340 (1R)	---	90%	1.17	---	11%	5.0	210
7	HD-1030	83%	83%	1.90	37%	37%	30.5	---
8	HD-1030	98%	15%	0.35	49%	12%	10.2	1,170
9	HD-1030	99%	1%	0.00	54%	5%	4.6	11,500
10	LCK	---	82%	1.52	---	30%	20.0	1,500
11	C-THM	---	85%	1.28	---	19%	10.1	1,600
12	ROW 0.8	---	68%	1.61	---	45%	38.9	710
13	Sand	---	11%	0.07	---	2%	0.5	1,550
14	WVG (Steamed)	---	92%	2.06	---	56%	45.2	340
15	ES-561 (Steamed)	---	22%	0.47	---	7%	6.4	1,560

*December, 1977

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The steaming schedule for Column 15 during Phase II was as follows. No steaming was conducted on sampling days 5, 12, 19, 27, and 34. The column was then steamed on sampling days 45, 53, 59, and 67. For the remainder of the period (44 days), the column was not steamed.

Chemical Parameters

The various chemicals and their dosages which were added at the Kansas City Water Treatment Plant during Phase II are given in Appendix D. This information has been tabulated for the day before and the day of sampling for possible future correlation with TTHM formation.

PHASE III

Regeneration Effects

At the conclusion of Phase II, the Westvaco WVG in Columns 1, 2, 3, and 14 and the ICI HD-1030 in Columns 7, 8, and 9 were sent back to the respective manufacturers for regeneration to restore the spent carbons to their virgin capacities with regard to specific parameters measured by each company.

According to the reports that were submitted by Westvaco, the Iodine Number and the Decolorizing Index of the spent carbons was less than that of the virgin carbon, indicating that these capacities had been diminished for removing TTHM and TOC. The first column of the series was the most affected, as would be expected, with measured decreases in Iodine Numbers and Decolorizing Index of 23% and 35%, respectively. The Volatiles Content of the Westvaco WVG rose from 1.1% to 7.4% in the carbon from Column 1. The Westvaco WVG from Column 14 which had been steamed periodically was only slightly less exhausted, with a measured decrease in Iodine Number and Decolorizing Index 21% and 31%, respectively. For this column, a Volatiles Content of 6.9% was measured.

For the regenerated Westvaco WVG the carbon from Column 1 was restored to 96% of its virgin capacity as measured by Iodine Number and 104% of its virgin capacity as measured by the Decolorizing Index. Its pore volume increased from 0.855 to 0.981 cc/g after regeneration. Columns 2 and 3 were restored to 97% and 89% of capacity, and 100% and 94% of capacity, respectively. The carbon that had been steamed was restored to 97% of its virgin Iodine Number and 99% of its virgin Decolorizing Index. Only the carbon from Phase II Columns 1, 2, and 3 was used in Phase III.

Manufacturers reported that carbon losses due to thermal reactivation ranged from 1.3% to 1.7% on a volume basis although an overall 12% reduction in volume was noted at the time the regenerated materials were reloaded into Columns 1, 2, and 3 in preparation for Phase III. The additional losses were attributed to the carbon that was utilized in sampling and to analysis prior to reactivation. On a large scale, sampling losses would be expected to be negligible. On the other hand, losses in shipment and handling were minimized in this procedure.

ICI noted in its report that the Iodine Number and Molasses Number of the spent carbons was less than that of the virgin carbon, indicating that these capacities had been utilized in removing TTHM and TOC. The first column of the series was the most affected, with a measured decrease in capacity of 14% and 20%, respectively.

The reactivated ICI HD-1030 from Column 7 was restored to 120% and 115% of its virgin capacities, as measured by Iodine Number and Molasses Number, while the carbon from Columns 8 and 9 was restored to 117% and 105% of capacity and 118% and 99% of capacity, respectively. The pore volume of the carbon from Column 7 increased from 0.845 to 0.962 cc/g as a result of reactivation.

Carbon losses due to thermal regeneration ranged from 1.5 to 5.8% on a volume basis, although a 14% reduction in volume was noted at the time that the regenerated materials were reloaded into Columns 7, 8, and 9 in preparation for Phase III.

Trihalomethane Removal

During Phase III, the influent concentrations of TTHM ranged from 1.3 µg/l to 82.8 µg/l, but were below 5 µg/l for most of the spring season. Therefore, little information could be gained about the adsorption of TTHM by the various adsorbents because of the very low influent values. As a result, plots of TTHM removal were not made for Phase III, although the results are presented in Appendix A.

Total Organic Carbon Removal

The influent level of TOC ranged from 2.79 to 3.45 mg/l during Phase III, with an average value of 3.00 mg/l. Table 5 gives the percentage of influent TOC removed by each adsorbent as well as the TOC adsorbed on a weight basis.

Westvaco WVG

By the end of Phase III, the three beds of once-regenerated Westvaco WVG removed approximately 85% of the influent TOC. About 60% was removed by the first bed in the series, while an additional 19% and 6.5% was removed by the second and third beds, respectively. In comparison, the undisturbed bed of virgin Westvaco WVG (Column 11) had removed about 62% of the influent TOC while the regularly backwashed bed of virgin Westvaco WVG had removed about 61%. Therefore, the performance of the once-regenerated, the undisturbed virgin, and the backwashed virgin beds of this adsorbent exhibited virtually the same removal of TOC. In Phase III the Westvaco WVG adsorbed more TOC than any of the other adsorbents.

During Phase III, the once-regenerated Westvaco WVG adsorbed about 38 mg per gram of adsorbent, whereas the virgin beds adsorbed only 33 mg of TOC per gram of adsorbent. Although the volumes of the adsorbents were the same, the weights of the material in each column were different. The regenerated carbon weighed about 12% less than an equal volume of virgin carbon.

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TABLE 5
TOC REMOVED DURING PHASE III (65 Days)

Column	Adsorbent	Column % TOC Removal	Cumulative % TOC Removal	mg TOC Adsorbed gram of Adsorbent	SPC Colonies per gram of Adsorbent (June, 1978)
1	$WVG_{(1R)}$	59.5%	59.5%	37.5	824,000
2	$WVG_{(1R)}$	18.9%	78.4%	12.0	820,000
3	$WVG_{(1R)}$	6.5%	84.9%	4.1	350,000
4	$XE\text{-}340_{(2R)}$	7.2%	7.2%	3.0	300
5	$IRA\text{-}904_{(v)}$	32.6%	39.8%	13.4	2,700
6	$WVG_{(v)}$	41.6%	81.4%	23.1	69,000
7	$HD\text{-}1030_{(1R)}$	43.0%	43.0%	32.3	844,000
8	$HD\text{-}1030_{(1R)}$	15.8%	58.8%	11.6	890,000
9	$HD\text{-}1030_{(1R)}$	8.4%	67.2%	6.3	238,000
10	$A\text{-}162_{(v)}$	46.6%	-----	18.3	3,100
11	$WVG_{(v)}$	61.6%	-----	32.9	850,000
12	$HD\text{-}1030_{(v)}$	51.0%	-----	32.0	590,000
13	Sand	2.4%	-----	0.4	440
14	$LCK_{(v)}$	32.7%	-----	23.7	180,000
15	$WVG_{(v)}$ (Backwashed)	61.2%	-----	32.7	52,000

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Figure 16 shows the removal of TOC by Columns 1, 11, and 15. The plots are almost identical and show that the effluent TOC concentrations followed the pattern of a modified breakthrough curve. Unlike a typical breakthrough curve, the TOC effluent concentration did not begin near zero and as before showed an immediate breakthrough of TOC. Backwashing did appear to result in a modest improvement in TOC removal.

Resin-Carbon Series Unit

In Phase III, Column 4 held the carbonaceous resin adsorbent (XE-340), Column 5 held the strong-base anion exchange resin (IRA-904) and Column 6 held granular activated carbon (WVG). At this time, the bed of carbonaceous adsorbent had been regenerated twice according to the manufacturer's specifications. The beds of IRA-904 and Westvaco WVG were in the virgin state.

Overall, approximately 81% of the influent TOC was adsorbed by this unit, making it comparable to the three columns in series of once-regenerated WVG. Only 7% of the influent TOC was removed by the bed of Ambersorb XE-340, while 33% was removed by the Amberlite IRA-904 and 42% by the Westvaco WVG.

Although the volume of each bed of these adsorbents was nearly equal, the weights were very different. The resin adsorbents had a greater density than the activated carbon by a factor of about 1.3. This factor had a large effect on the calculated TOC adsorption on a weight basis. Approximately 3.0, 13.4 and 23.1 milligrams of TOC were adsorbed per gram of Ambersorb XE-340, Amberlite IRA-904, and Westvaco WVG, respectively. TOC adsorption on the virgin bed of Westvaco WVG was considerably less than that observed on other beds of this carbon which did not follow resin adsorbents and were subject to higher influent TOC loadings. The lower percentage removal of TOC on the Westvaco WVG may indicate that the resins were removing a portion of the TOC that would have been adsorbed by the activated carbon, thus reducing the fraction of carbon-adsorbable organics. Alternately, some organic matter that was not well adsorbed by the carbon bed may have been eluted from the resins.

Figure 17 shows the removal of TOC by each of the adsorbents in the series. Under no circumstances was the influent TOC totally adsorbed by any, or all, of the beds in the series. Each adsorbent appeared to remove a certain fraction of the influent TOC consistently, with the effluent concentrations of TOC from the three adsorbents being nearly constant throughout the period.

ICI HD-1030

The three beds of once-regenerated ICI HD-1030 removed approximately 67% of the influent TOC with about 43% removal achieved by the first bed in the series, 16% removal by the second bed, and 8% removal by the last bed in the series. In comparison, the virgin bed of ICI HD-1030 carbon (Column 12) removed about 51% of the influent TOC. However, on a weight basis the removal of TOC was nearly identical at 32.9 and 32.3 mg TOC/g of adsorbent respectively. The weight of the virgin ICI HD-1030 carbon exceeded that of the once-regenerated ICI HD-1030 by a factor of about 1.2.

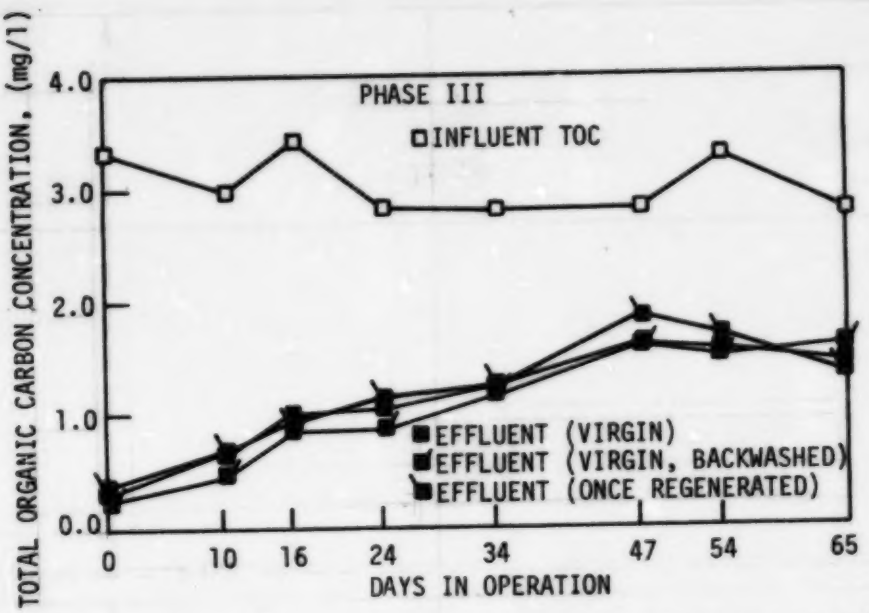

Figure 16. Adsorption of TOC by Westvaco WVG granular activated carbon.

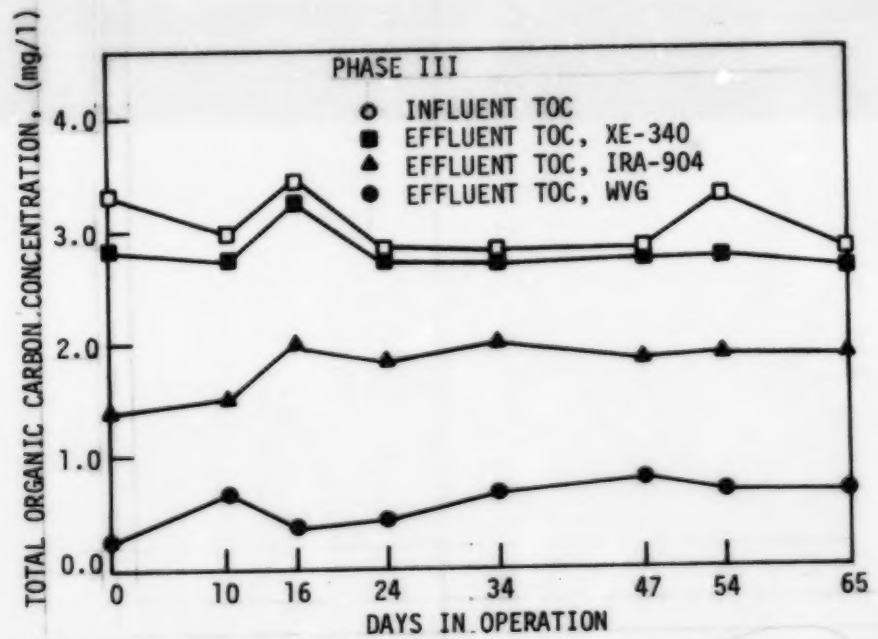

Figure 17. Adsorption of TOC by series unit containing Ambersorb XE-340, Amberlite IRA-904, and Westvaco WVG.

Figure 18 shows the removal of TOC by virgin and once-reactivated ICI HD-1030, respectively. Both plots illustrate that some initial breakthrough of TOC occurred and was followed by a gradual increase in the effluent concentration with time.

Diamond Shamrock A-162

The virgin Diamond Shamrock A-162 adsorbed about 47% of the influent TOC during Phase III. This was higher than the 33% removal observed for Amberlite IRA-904, the other strong-base anion exchange resin used in Column 5. Since that resin was preceeded by the carbonaceous resin, the apparent removal of TOC by Amberlite IRA-904 in the series may have been slightly reduced. Amberlite IRA-904 adsorbed about 18 milligrams of TOC per gram of adsorbent, or about one-half the value calculated for the activated carbons.

Figure 19 shows the adsorption of TOC by the A-162 in Column 10. Once again a familiar pattern is displayed in the nearly horizontal effluent concentration curve. This material appeared to remove a constant fraction of the influent TOC from the first to the last day of operation, indicating a continuing effectiveness in removing certain organic constituents in the influent and an inability to remove others.

Filter Sand

A bed of filter sand was included in this phase to act as a control. Figure 20 shows the TOC in the effluent. As in Phase II, the bed of filter sand was calculated to remove about 2% of the influent quantity of TOC. Therefore, essentially no TOC removal was accomplished by the filter sand since the precision of this measurement is estimated as ± 3%.

Union Carbide LCK

Virgin Union Carbide LCK removed about 33% of the influent of TOC during Phase III. This was in close agreement with the results obtained from Phase II. When compared to the other activated carbons that were studied during Phase III, the Union Carbide LCK achieved the lowest TOC removal and was equivalent to the Amberlite IRA-904.

The Union Carbide LCK adsorbed approximately 24 milligrams of TOC per gram of adsorbent, indicating that it was more effective than the resin on a weight basis. This figure agreed closely with the value derived at the end of Phase II. Figure 21 shows the removal of TOC by the Union Carbide LCK during Phase III.

Threshold Odor Number Removal

Only a few samples of column effluents were analyzed for TON removal during Phase III. From the data obtained for this period, it appears that the adsorbents in Columns 10 through 15 tended to increase the TON values while a depth of approximately 7.75 ft of once-regenerated ICI HD-1030 and a 31-in. deep bed of virgin HD-1030 were successful in producing an effluent with a TON of 1.

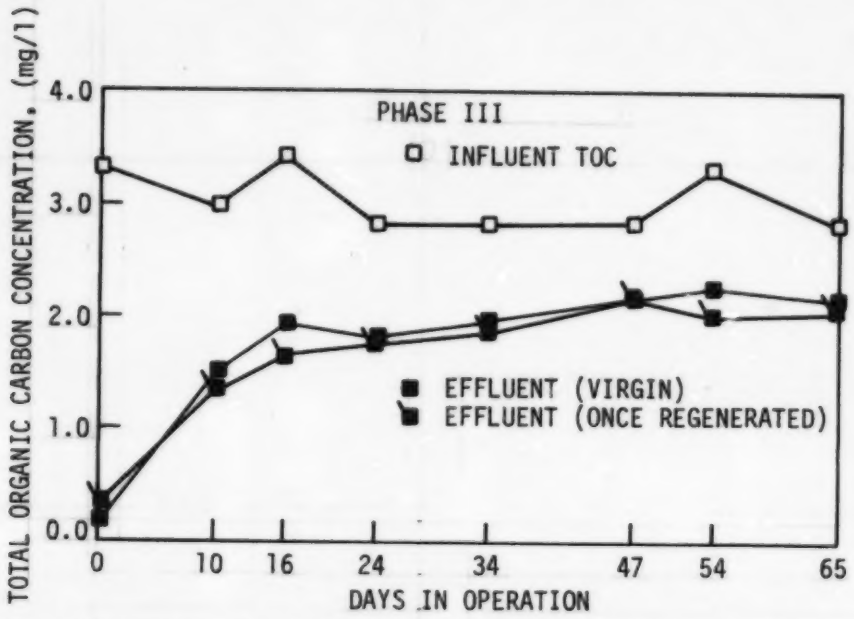

Figure 18. Adsorption of TOC by ICI HD-1030 granular activated carbon.

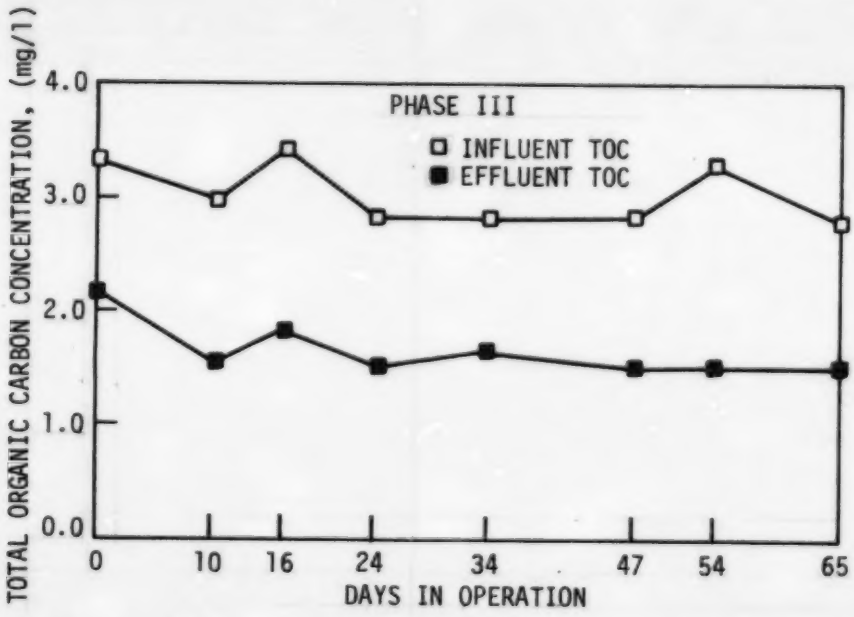

Figure 19. Adsorption of TOC by Diamond Shamrock A-162 strong base anion exchange resin.

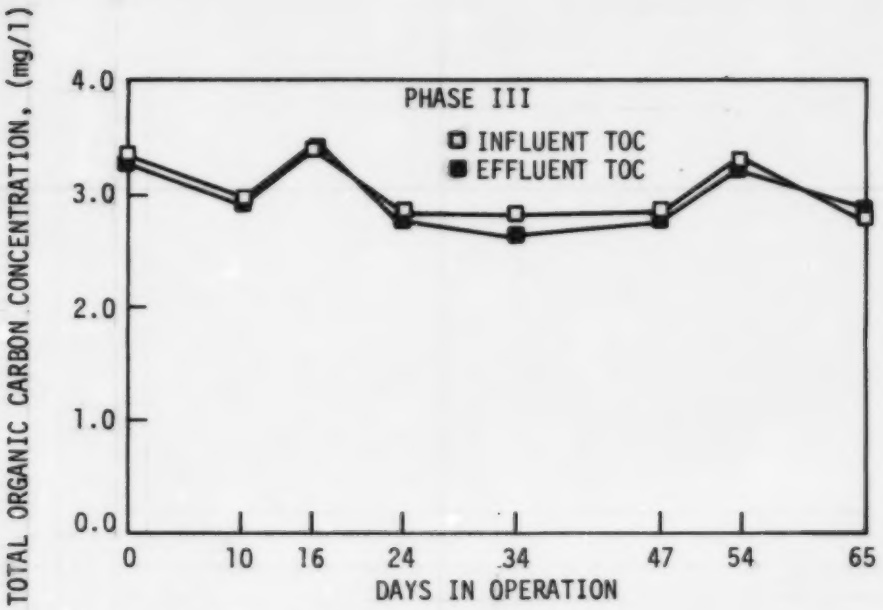

Figure 20. Adsorption of TOC by filter sand.

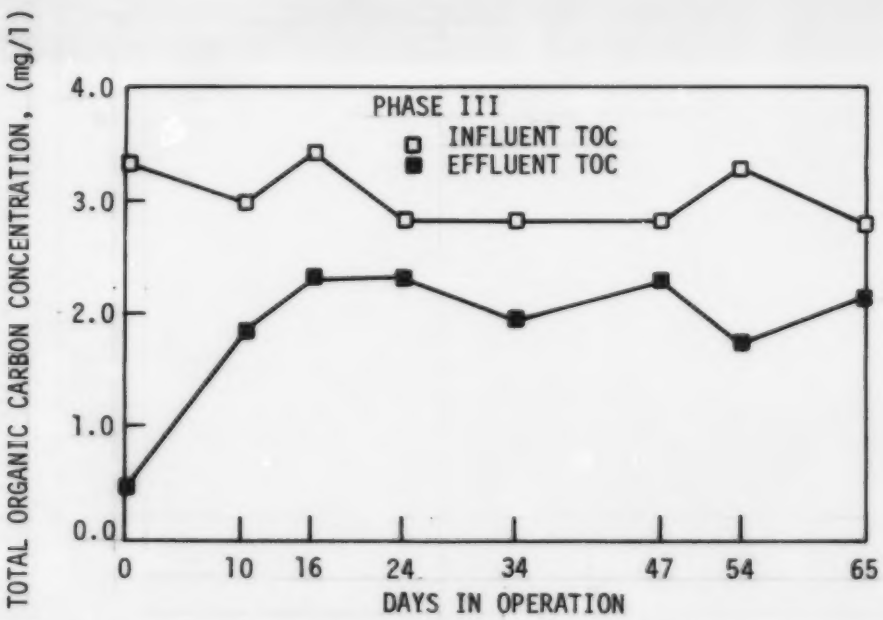

Figure 21. Adsorption of TOC by Union Carbide LCK granular activated carbon.

Biological Growth

No steaming experiments were conducted during Phase III. Instead, all of the adsorbents were allowed to develop biological populations freely. Column 15, which contained virgin Westvaco WVG, was backwashed vigorously on each sampling date while all of the other columns remained undisturbed.

The results of the bacterial analyses which were performed on media samples taken at the end of Phase III are presented in Table 5. These samples were taken from the upper few inches each of the adsorbent beds. Although the analyses are only comparative, they give some indication of the levels of biological growth that had developed on the adsorbents.

Both of the series units containing the Westvaco WVG and ICI HD-1030 carbons that had been once-regenerated displayed a similar pattern. The first two beds had high bacterial counts of about 850,000 colonies per gram, while the third bed had a somewhat lower count of about 300,000 colonies per gram. The virgin beds of these two carbons, Columns 11 and 12, had values approximately in the range of a comparable once-regenerated bed.

The strong-base anion exchange adsorbents supported similar biological growths of approximately 3000 colonies per gram. This was much lower than the values observed for the activated carbons, but higher than the approximately 300 to 400 colonies per gram found on the carbonaceous resin and the filter sand.

The Union Carbide LCK supported about 180,000 colonies per gram. Lower values were found only on the virgin Westvaco WVG that followed the two resin beds and on the virgin Westvaco WVG that was backwashed periodically. These latter beds yielded approximately 70,000 and 52,000 colonies per gram, respectively.

Duration of Study

In studying the removal of TTHM and TOC by adsorbents in beds, it appears that a sufficiently long time period should be allowed in order to observe complete exhaustion of the bed and to assess the potential for desorption of organic substances from the bed. Longer experimental cycles also give insight into the effect of gradually increasing or sporadically high influent organic loadings on adsorbents that are near exhaustion. Experimental periods of at least 130 days appear to be needed to develop reliable data for these kinds of comparisons.

PHASE IV

Regeneration Effects

At the conclusion of Phase III, the Westvaco WVG that had been in Columns 1, 2, 3, and 11 and the ICI HD-1030 that had been in Columns 7, 8, 9, and 12 were sent back to the manufacturers for regeneration.

Westvaco reported that the spent carbons showed a decrease in capacity from the virgin and once-reactivated carbon values for Iodine Number and Decolorizing Index. The once-reactivated carbon in Column 1 and the virgin carbon in Column 11 had a measured decrease in capacity of 20% and 47%, and 18% and 40%, respectively. The Volatile Solids content ranged from 2.3 to 4.6%. The reactivated carbons from Columns 1, 2, 3, and 11 were restored to 100% and 110% of virgin capacity, 102% and 110% of virgin capacity, 105% and 108% of virgin capacity, and 103% and 100% of virgin capacity, respectively. When the reactivated carbon was put back into Columns 1, 2, 3, and 10 in preparation for Phase IV, it was noted that the losses on a volume basis amounted to 16%, 11%, 8%, and 8% respectively. The losses were due in part to sampling for laboratory testing and to thermal reactivation.

ICI found a decrease in capacity of the spent carbons from the virgin and once-reactivated carbon values for Iodine Number and Molasses Number. Column 7, which held the once-reactivated carbon, and Column 12, which held the virgin carbon, had a measured decrease in capacity of 19% and 15%, and 12% and 16%, respectively. The reactivated carbons from Columns 7, 8, 9, and 12 were restored to 118% and 115% of virgin capacity, 121% and 113% of virgin capacity, 121% and 112% of virgin capacity, and 112% and 101% of virgin capacity, respectively. When the reactivated carbon was put back into Columns 7, 8, 9, and 12 in preparation for Phase IV, it was noted that the losses on a volume basis amounted to 13%, 8%, 6%, and 6% respectively. Again, the losses were due in part to sampling for laboratory testing and to thermal reactivation.

Trihalomethane Removal

The influent concentration of TTHM ranged from 7 µg/l to 137 µg/l during Phase IV. Table 6 lists the percentage of the influent TTHM that was removed by each adsorbent. Note that for Columns 1, 4, 6, 7, 10, and 11, intermediate sampling points were created for this phase and were designated "top," "middle," and "bottom." Table 6 gives both the volume of media and the weight of media associated with each sampling point. For instance, the sampling point port referred to as "Column 1 Top" was located at a depth representing 0.042 ft^3 (or 517 grams) of media; there was 0.30 ft^3 (or 3698 grams) of media between sampling ports "Column 1 Top" and "Column 1 Middle." The total volume of Column 1 was 0.442 ft^3 or 5448 grams. For the columns that had intermediate sampling points, the overall TTHM removal on a weight basis is given in parentheses.

Westvaco WVG

At the end of Phase IV, the three columns in series of twice-activated Westvaco WVG had removed approximately 99% of the influent TTHM. Expressed on an individual column basis, the first bed removed about 75% while the second and third beds removed about 22% and 2%, respectively. Column 10 and Column 11 contained almost the same volume of Westvaco WVG as did Column 1, except that the degree of reactivation was different. Column 10, which contained once-reactivated Westvaco WVG removed 67% of the influent TTHM. Column 11 which contained virgin Westvaco WVG removed 66%.

TABLE 6
TTHM AND TOC REMOVALS DURING PHASE IV

Column	Adsorbed	Column % TTHM Removal	Cumulative % TTHM Removal	Volume of Media (ft^3)	Weight of Media (g)	mg TTHM Adsorbed / Gram of Adsorbent	mg TOC Adsorbed / Gram of Adsorbent
1 Top	$WVG_{(2R)}$	11.9%	11.9%	0.042	517	2.18	----
1 Middle	$WVG_{(2R)}$	46.6%	58.5%	0.300	3,698	1.19	----
1 Bottom	$WVG_{(2R)}$	16.7%	75.2%	0.100	1,233	1.28(1.31)	45.3
2	$WVG_{(2R)}$	22.4%	97.6%	0.467	5,402	0.39	13.0
3	$WVG_{(2R)}$	1.70%	99.3%	0.483	5,521	0.03	6.46
*4 Top	$XE\text{-}340_{(3R)}$	27.3%	27.3%	0.184	3,133	5.47	----
*4 Middle	$XE\text{-}340_{(3R)}$	19.1%	46.4%	0.300	5,107	2.35	----
*4 Bottom	$XE\text{-}340_{(3R)}$	7.2%	53.6%	0.108	1,839	2.45(3.34)	15.6
*5	$IRA\text{-}904_{(1R)}$	-30.8%	22.8%	0.608	10,442	-1.86	13.0
*6 Top	$WVG_{(v)}$	9.8%	32.6%	0.175	2,013	3.07	----
*6 Middle	$WVG_{(v)}$	12.4%	45.0%	0.300	3,451	2.26	----
*6 Bottom	$WVG_{(v)}$	8.8%	53.8%	0.117	1,346	4.10(2.86)	109.1
7 Top	$HD\text{-}1030_{(2R)}$	32.7%	32.7%	0.042	424	7.3	----
7 Middle	$HD\text{-}1030_{(2R)}$	32.8%	65.5%	0.300	3,026	1.02	----
7 Bottom	$HD\text{-}1030_{(2R)}$	11.3%	76.8%	0.108	1,090	0.98(1.59)	38.4
8	$HD\text{-}1030_{(2R)}$	15.1%	91.9%	0.475	4,495	0.32	11.9
9	$HD\text{-}1030_{(2R)}$	4.3%	96.2%	0.416	4,558	0.09	7.46
10 Top	$WVG_{(1R)}$	27.6%	27.6%	0.083	950	2.92	----
10 Middle	$WVG_{(1R)}$	30.2%	57.8%	0.300	3,435	0.89	----
10 Bottom	$WVG_{(1R)}$	9.4%	67.2%	0.100	1,145	0.83(1.22)	44.0
11 Top	$WVG_{(v)}$	28.3%	28.3%	0.075	846	3.37	----
11 Middle	$WVG_{(v)}$	26.1%	54.4%	0.300	3,384	0.78	----
11 Bottom	$WVG_{(v)}$	11.5%	65.9%	0.108	1,218	0.96(1.22)	49.4
12	$HD\text{-}1030_{(1R)}$	71.6%	---	0.483	4,699	1.54	39.4
13	$HD\text{-}1030_{(v)}$	62.1%	---	0.483	5,266	1.19	32.8
14	$WVG_{(v)}$ (Undisturbed)	67.2%	---	0.592	6,810	1.24	46.8
15	$WVG_{(v)}$ (Steamed)	95.8%	---	0.600	6,810	1.77	55.6

*Columns 4, 5 and 6 were operated at a flow rate of 10 gpm/sf.

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Columns 14 and 15, which contained virgin Westvaco WVG, were employed in a study of the effect of steaming on the development of biological growth on this adsorbent. Column 14 remained undisturbed for the period while Column 15 was steamed on each sampling day. Column 14 was found to remove about 67% of the influent TTHM. This was almost identical to the result observed for Columns 10 and 11. However, the carbon bed that had been regularly steamed was found to remove about 96% of the influent TTHM. This represented an increase in removal of approximately 43% over an identical, unsteamed bed of the same material. In Phase II, an increase of only 24% was observed but the carbon had not been steamed on every sampling day.

The TTHM removals in Columns 1, 10, 11, 14, and 15 were calculated to be 1.31 1.22, 1.22, 1.24, and 1.77 mg/g. Therefore, the twice-regenerated carbon appeared to have a slightly greater capacity for TTHM than the once-regenerated and virgin carbons.

Figure 22 shows the removal of TTHM by Westvaco WVG in columns 1, 10, and 11. In each case, essentially all of the TTHM was adsorbed during the first 24 days of operation. After this time, breakthrough gradually began to occur. It is evident that the once-regenerated and virgin carbons began to break through at a faster rate than the twice-regenerated carbon, although all of the beds had the same effluent concentration after 100 days of operation. It did not appear that these beds had been totally exhausted after 129 days of operation since some degree of removal was still occurring.

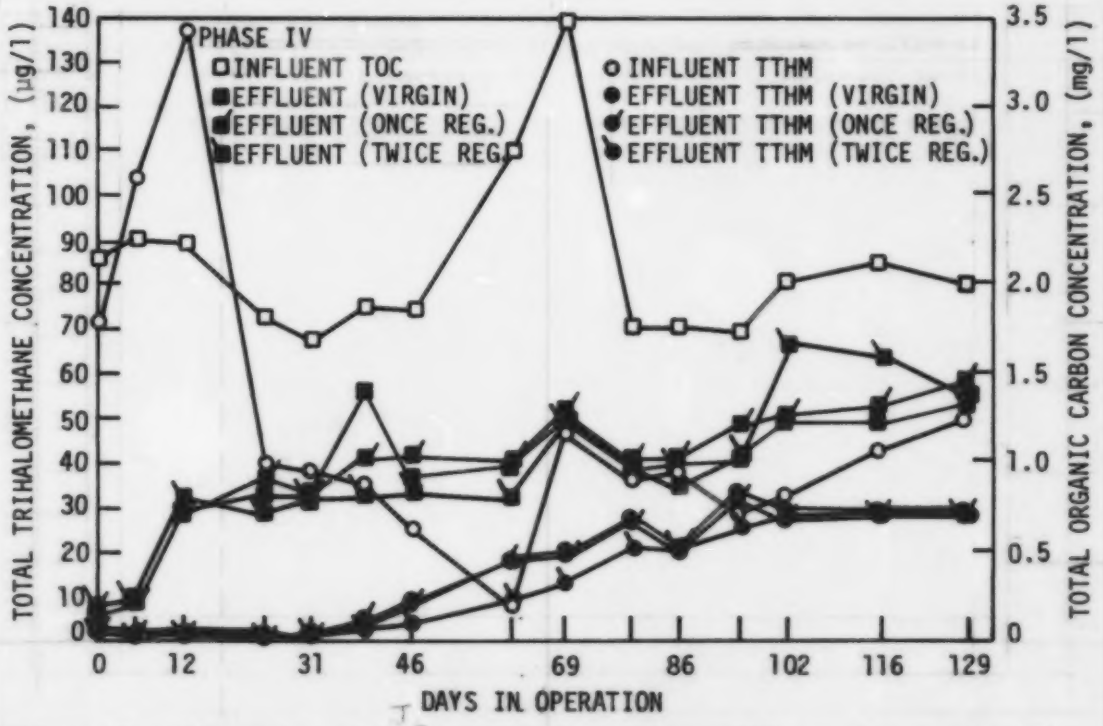

Figure 22. Adsorption of TTHM and TOC by Westvaco WVG granular activated carbon.

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Figure 23 shows the removal of TTHM by the unsteamed and steamed carbon beds, Columns 14 and 15. Column 14, which held virgin Westvaco WVG, displayed a pattern for removal of TTHM similar to that of the other beds of Westvaco WVG except that it appeared to exhibit breakthrough earlier.

Column 15 held virgin Westvaco WVG which had been steamed each sampling day. The removal of TTHM by this carbon bed was markedly different from the other carbon beds in that no indication of TTHM breakthrough occurred. The repeated steaming may have partially regenerated the carbon bed by volatilizing and stripping off the previously adsorbed TTHM, or by creating more small pores thus increasing the carbon's ability to adsorb the TTHM.

Carbon-Resin Series Unit

During Phase IV, Columns 4, 5, and 6 each held approximately 3-ft deep beds of Ambersorb XE-340 (regenerated for the third time following Phase III), Amberlite IRA-904 (regenerated following Phase III), and virgin Westvaco WVG, respectively. This particular unit was operated at an increased flow rate of 2 gpm which resulted in an hydraulic loading rate of 10 gpm/ft^2. The empty bed contact time for this system was about 2.24 min, or one-fifth that of the other contactors. As a result, the adsorbents in this unit experienced a far higher loading of TTHM than the other adsorbents utilized during this phase of the study. This higher loading rate was employed in an attempt to exhaust the resin materials and to compare the performance of the carbon at high and low flow rates.

Overall, approximately 54% of the influent TTHM was removed by this unit. While 54% was removed by the Ambersorb XE-340 alone, 31% appeared to be contributed to the effluent stream by the succeeding bed of Amberlite IRA-904. The final bed containing virgin Westvaco WVG removed another 31% of the TTHM (based on the influent level to the first bed in the series) which brought the total removal back to 54%. For the Ambersorb XE-340 and the Westvaco WVG, these removals were approximately one-half of the percentage removals observed in earlier runs at lower flow rates. On day 12, the influent TTHM value increased dramatically, resulting in an erratic increase in TTHM in the last two column effluents. While this may have produced a slightly erroneous figure for the percent removal of TTHM by the Amberlite IRA-904 the overall removal would still have been negative since the effluent concentrations were always greater than the influent concentrations.

At the conclusion of Phase IV, the adsorbents had removed 3.34, -1.86, and 2.86 mg TTHM/g, respectively. The virgin Westvaco WVG, operated at the higher flow rate, had removed twice the amount of TTHM per gram of adsorbent as the other activated carbons.

Figures 24, 25, and 26, show the removal of TTHM by Columns 4, 5, and 6 during Phase IV. All of the adsorbents showed some initial passage of TTHM. TTHM effluent concentrations rose rapidly during the first two weeks of operation and then remained relatively constant for the following 7 to 8 weeks, as column influent concentrations declined, replicating the influent TTHM pattern observed in the previous year.

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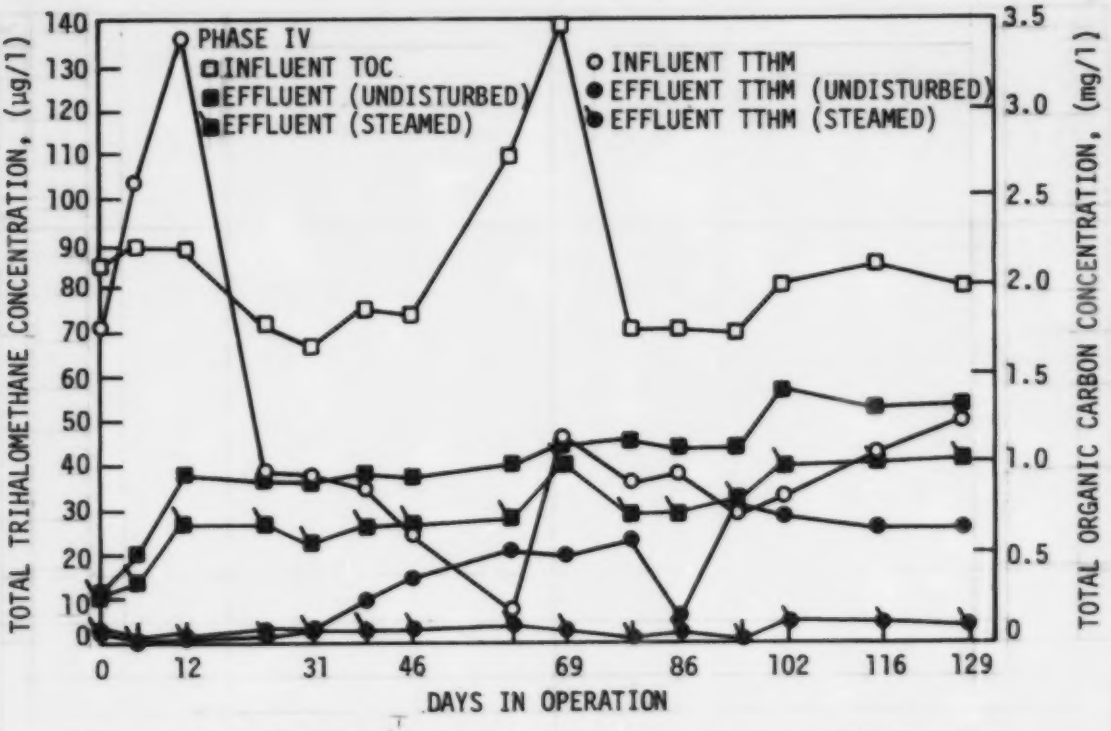
PHASE IV
INFLUENT TOC
EFFLUENT (UNDISTURBED)
EFFLUENT (STEAMED)
INFLUENT TTHM
EFFLUENT TTHM (UNDISTURBED)
EFFLUENT TTHM (STEAMED)
TOTAL TRIHALOMETHANE CONCENTRATION, (µg/l)
TOTAL ORGANIC CARBON CONCENTRATION, (mg/l)
DAYS IN OPERATION
0 12 31 46 69 86 102 116 129
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5

Figure 23. Adsorption of TTHM and TOC by Westvaco WVG granular activated carbon.

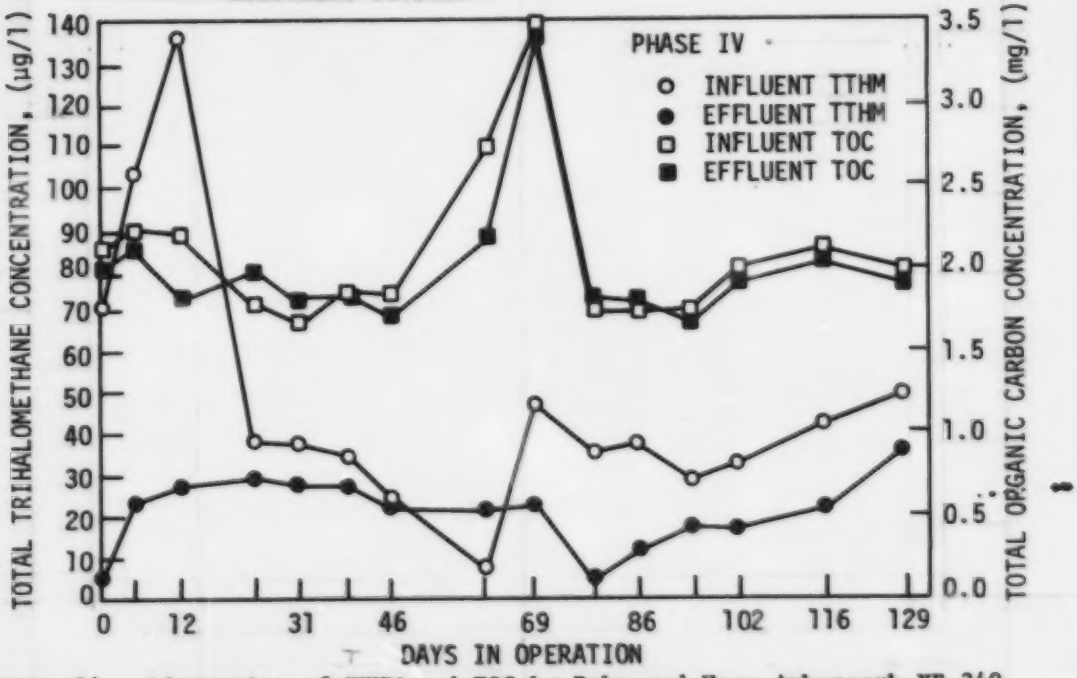
PHASE IV
INFLUENT TTHM
EFFLUENT TTHM
INFLUENT TOC
EFFLUENT TOC
TOTAL TRIHALOMETHANE CONCENTRATION, (µg/l)
TOTAL ORGANIC CARBON CONCENTRATION, (mg/l)
DAYS IN OPERATION
0 12 31 46 69 86 102 116 129
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5

Figure 24. Adsorption of TTHM and TOC by Rohm and Haas Ambersorb XE-340 carbonaceous resin.

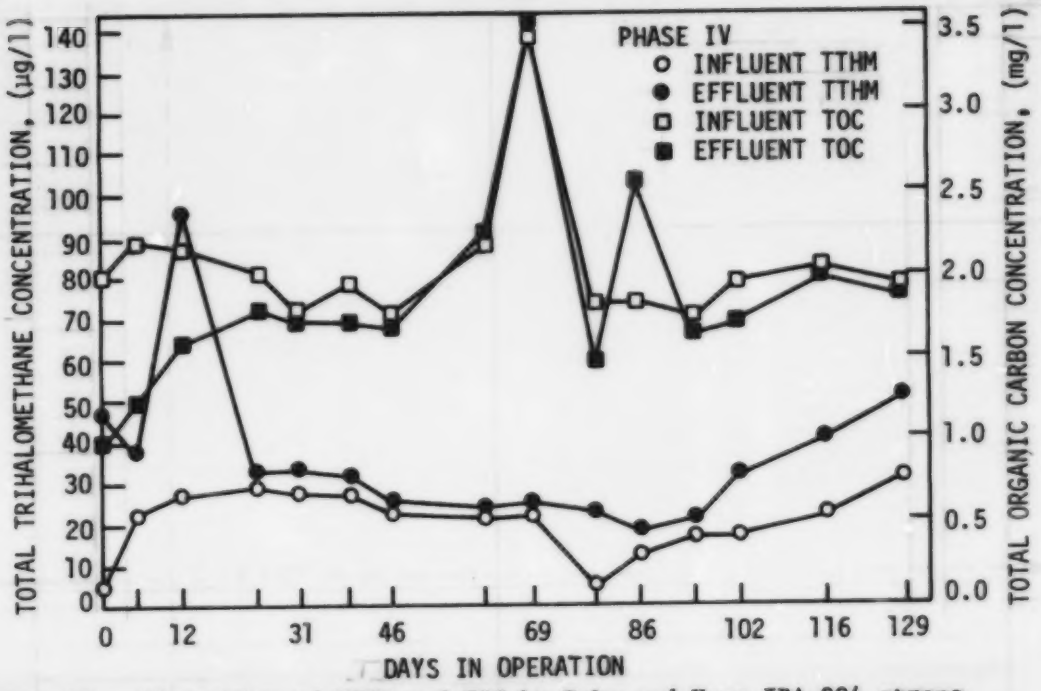
PHASE IV
INFLUENT TTHM
EFFLUENT TTHM
INFLUENT TOC
EFFLUENT TOC
TOTAL TRIHALOMETHANE CONCENTRATION, (µg/l)
TOTAL ORGANIC CARBON CONCENTRATION, (mg/l)
DAYS IN OPERATION
0 12 31 46 69 86 102 116 129
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5

Figure 25. Adsorption of TTHM and TOC by Rohm and Haas IRA-904 strong base anion exchange resin.

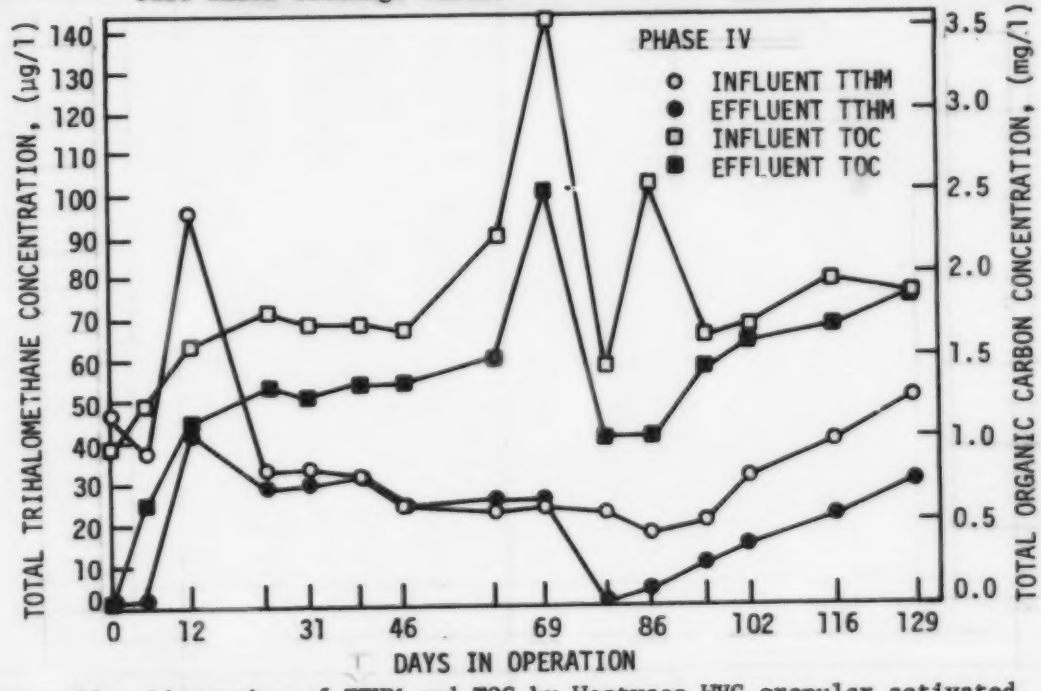
PHASE IV
INFLUENT TTHM
EFFLUENT TTHM
INFLUENT TOC
EFFLUENT TOC
TOTAL TRIHALOMETHANE CONCENTRATION, (µg/l)
TOTAL ORGANIC CARBON CONCENTRATION, (mg/l)
DAYS IN OPERATION
0 12 31 46 69 86 102 116 129
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5

Figure 26. Adsorption of TTHM and TOC by Westvaco WVG granular activated carbon (Virgin).

ICI HD-1030

The three beds in series of twice-reactivated ICI HD-1030 removed approximately 96% of the influent TTHM. The first bed removed about 77% of the total, while 15% and 4% were removed by the remaining two beds in the series. Columns 12 and 13 which contained once-reactivated and virgin ICI HD-1030, were found to remove 72% and 62%, respectively. The reactivated ICI HD-1030 appeared to remove slightly more TTHM than the virgin carbon, the capacity for TTHM increasing with successive reactivations. In comparison, only the Westvaco WVG that had been twice-reactivated appeared to perform better. The differences between each of the carbons is 10% or less, which indicated that they were approximately equivalent during this run.

At the end of Phase IV, the twice-reactivated ICI HD-1030 adsorbed about 1.6 mg TTHM/g while the once-reactivated bed adsorbed about 1.5 mg TTHM/g. The virgin bed adsorbed only about 1.2 mg TTHM/g during this period.

Figure 27 shows the results of TTHM removal by the twice-reactivated, once-reativated, and virgin beds of LBC. All three columns appeared to perform similarly and did not appear to be totally exhausted by the end of the 129 days of operation.

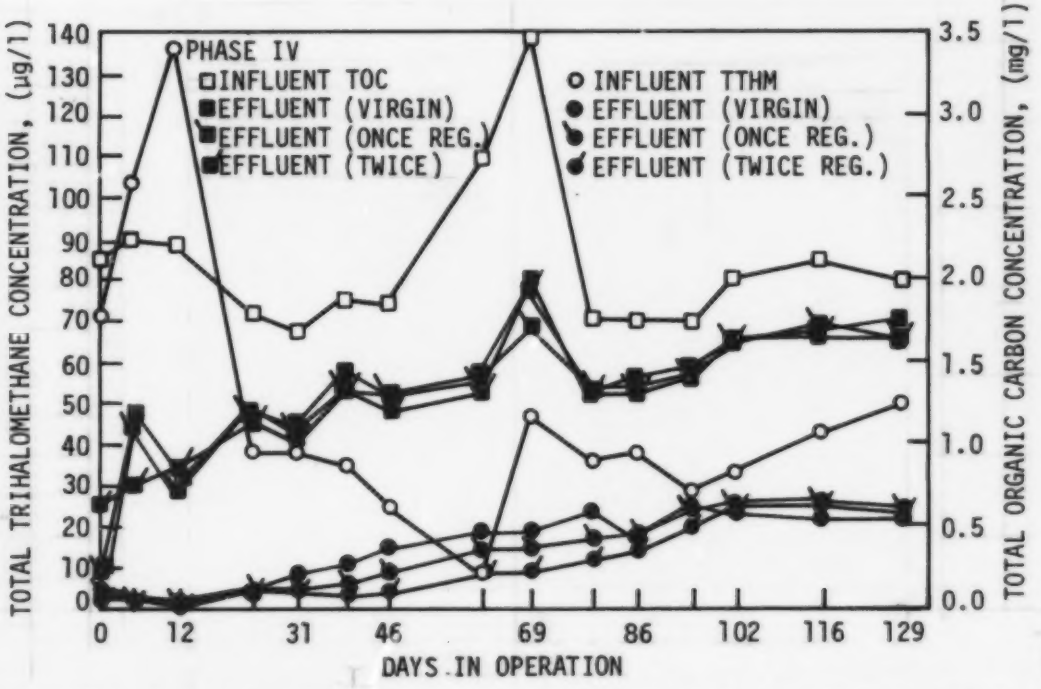

Figure 27. Adsorption of TTHM and TOC by ICI HD-1030 granular activated carbon.

Total Organic Carbon Removal

The influent level of TOC ranged from 1.70 to 3.47 mg/l during Phase IV, with an average value of 2.0 mg/l. Table 7 gives the percentage of the influent TOC that was removed by each adsorbent while Table 6 lists the TOC adsorbed per gram of adsorbent.

Westvaco WVG

By the close of Phase IV, the three beds of twice-reactivated Westvaco WVG had adsorbed approximately 78% of the influent TOC. About 55% was adsorbed by the first of the three beds in series, while about 15% and 8% was adsorbed by the second and third beds. The bed of once-regenerated Westvaco WVG that was operated in parallel to Column 1 removed about 50% of the influent TOC while a virgin bed of this carbon was found to remove about 56%. There was, therefore, essentially no difference in TOC removal between the reactivated and the virgin Westvaco WVG. The bed of virgin Westvaco WVG that had been steamed on each sampling day was found to remove about 63% of the total influent TOC. This improvement in TOC removal was about the same as that observed in Phase II.

Column 1, which contained the twice-reactivated Westvaco WVG removed about 45 milligrams of TOC per gram of adsorbent. Column 10, which contained once-reactivated carbon, had about the same capacity. A bed of virgin Westvaco WVG contained in Column 11 adsorbed 49 mg TTHM/g. Therefore, no great differences between these materials were observed. The values obtained in Phase IV are higher than the 38 and 33 mg/g capacities calculated for the once-reactivated and the virgin Westvaco WVG at the end of Phase III. Column 15, the steamed bed, exhibited an adsorption capacity of about 56 mg/g which reflected the increased removals due to the effects of steaming.

Figure 22 shows the TOC removal by the twice-reactivated, the once-reactivated, and the virgin Westvaco WVG during Phase IV. The TOC removals by the two columns that contained unsteamed and steamed virgin Westvaco WVG are represented by Figure 23. A similar pattern in the effluent concentration curves can be noted for these columns except that the steamed bed achieved a higher TOC removal.

Resin-Carbon Series Unit

As previously discussed, this unit was comprised of three beds in series containing Ambersorb XE-340, Amberlite IRA-904, and virgin Westvaco WVG, respectively. The unit was operated at an application rate of 10 gpm/ft^2 and had an empty bed contact time of 2.24 minutes.

Approximately 5% of the influent quantity of TOC was removed by the first bed in the series, while the second and third beds removed about 4% and 25%, respectively, for a total TOC removal of 34%. When compared to the results obtained for these three adsorbents during Phase III (7%, 33%, and 42%), it is obvious that the TOC removal performances of the Amberlite IRA-904 and Westvaco WVG were impaired by the higher flow rate. Ambersorb XE-340, which did not remove TOC to any great degree in either phase, was not

TABLE 7
TOC REMOVED DURING PHASE IV

Column #	Adsorbent	Column % TOC Removal	Cumulative % TOC Removal	SPC Colonies per gram of Adsorbent (Nov., 1978)
1	$WVG_{(2R)}$	54.5%	54.5%	5400
2	$WVG_{(2R)}$	15.4%	70.0%	2200
3	$WVG_{(2R)}$	7.9%	77.9%	200
*4	$XE\text{-}340_{(3R)}$	5.2%	5.2%	250
*5	$IRA\text{-}904_{(1R)}$	4.5%	9.7%	1000
*6	$WVG_{(v)}$	24.6%	34.3%	100
7	$HD\text{-}1030_{(2R)}$	38.5%	38.5%	1800
8	$HD\text{-}1030_{(2R)}$	11.8%	50.3%	350
9	$HD\text{-}1030_{(2R)}$	7.5%	57.8%	400
10	$WVG_{(1R)}$	50.4%	----	6500
11	$WVG_{(v)}$	55.7%	----	5000
12	$HD\text{-}1030_{(1R)}$	38.3%	----	1500
13	$HD\text{-}1030_{(v)}$	35.7%	----	1350
14	$WVG_{(v)}$ (Undisturbed)	52.8%	----	4000
15	$WVG_{(v)}$ (Steamed)	62.7%	----	250

*Columns 4, 5 and 6 were operated at a flow rate of 10 gpm/sf.

particularly affected by the change in flow rate. However, TOC removal by the Amberlite IRA-904 was markedly reduced. The Westvaco WVG withstood higher hydraulic loadings fairly well, removing roughly one-half of the influent TOC at a five times higher flow rate.

Columns 4, 5, and 6 adsorbed approximately 16, 13, and 109 mg TOC/g during Phase IV. At the end of Phase III, these figures were about 3, 13, and 23 mg/g, respectively.

Figures 24, 25, and 26 show the removal of TOC for Columns 4, 5, and 6 of the resin-carbon series during Phase IV. The effluent concentration curve for the Ambersorb XE-340 essentially overlays the influent curve thus indicating that little removal occurred over the period. However, the curve for the Amberlite IRA-904 indicates that most of the removal occurred during the initial 46 days of operation and little removal was achieved after that time. (The sample analyzed on day 86 is thought to be a poor datum point.) In contrast to the other two adsorbents, the virgin Westvaco WVG began by removing almost all of the influent TOC and rapidly reached a point where it removed a constant fraction of the incoming TOC.

ICI HD-1030

The three beds of twice-reactivated ICI HD-1030 removed approximately 58% of the influent TOC, with about 39% removal occurring in the first bed in the series, 12% removal in the second bed, and 8% removal in the final bed. In comparison, the once-reactivated and virgin ICI HD-1030 carbon beds removed 38% and 36% of the TOC. Therefore, reactivation of this carbon did not affect its performance with regard to TOC removal. Once again, the ICI HD-1030 did not remove as much TOC as the Westvaco WVG during this period, and the removals were somewhat lower than those observed for ICI HD-1030 in Phase III.

Columns 7, 12, and 13 adsorbed approximately 38, 39, and 32 mg TOC/g. This indicates that the reactivated carbons may have a slightly higher capacity for TOC than the virgin ICI HD-1030 although the values are comparable. These values compare quite favorably with the 32 mg/g TOC capacity that was obtained for both the once-reactivated and the virgin ICI HD-1030 carbons at the end of Phase III.

Figure 27 shows the removal of TOC by ICI HD-1030 in Columns 7, 12, and 13 during Phase IV. While the twice-regenerated ICI HD-1030 initially passed about 0.6 mg/l of TOC, the once-regenerated carbon bed passed only about 0.2 mg/l TOC and the virgin carbon bed adsorbed almost all of the incoming TOC. Shortly thereafter, the effluent TOC concentrations of these last two beds rose sharply to a level approximately equal to that of the twice-regenerated bed.

Threshold Odor Number

Because of the large number of samples, a schedule was devised whereby only a few samples were taken and analyzed for TON on any one day. Usually, samples taken from a series unit or from some logical sequence of the single

columns were analyzed so that closely related adsorbents could be compared. A complete listing of the results can be found in Appendix C and a summary of the results is presented in Table 8.

From the data obtained for this period, it again appeared that the TON of the finished Kansas City water was generally low and that the various activated carbons did not consistently reduce the odor values. On the other hand, the Amberlite IRA-904 increased the odor value while the succeeding bed of virgin Westvaco WVG subsequently reduced TON. The ICI HD-1030 series unit containing the twice-regenerated carbon appeared to be more successful in reducing the odor value than the Westvaco WVG unit. The remaining columns were more variable in their responses, generally altering rather than eliminating odors.

Biological Growth

During Phase IV, Column 15, which contained virgin Westvaco WVG, was steamed on each sampling day while the rest of the adsorbents were allowed to develop biological populations freely. The results of the bacterial analyses performed on media samples taken at the end of Phase IV are presented in Table 7. Overall, all counts obtained were very low because of the low November water temperatures.

In the series units containing activated carbon, the higher bacterial populations were generally found on the first bed while lower populations were found on the last two beds of the series. Higher populations were found on the Westvaco WVG than on the ICI HD-1030 carbons, which may perhaps be related to observed differences in TOC removal.

The Ambersorb XE-340 yielded a very small population of microorganisms, while the Amberlite IRA-904 yielded slightly more. Suprisingly, the virgin Westvaco WVG which completed this series unit also yielded a very low population, much lower than any of the other carbons. The high flow rate may have had some effect on organism attachment.

These bacterial analysis results again highlight the important influence of temperature on bacterial growth.

Table 8 Summary of TON Removal Results

Adsorbent Column (& Phase)	Influent TON Range	Effluent TON Range	Number of Times Effluent TON		
			Was Less Than Influent TON	Equalled Influent TON	Exceeded Influent TON
WVG 1 (I)	1-4	1-2	6	4	
WVG 1 (II)	1-3	1-8	3		2
WVG 2 (I)	1-4	1-6	3	4	1
WVG 2 (II)	1-3	1-12	2		3
WVG 3 (I)	1-4	1-2	8	2	
WVG 3 (II)	1-3	1-8	3	1	1
ES-561 (I)	1-4	2-6	2	3	5
ES-561 (regenerated) (II)	2-3	2-4	1	3	1
ES-561 (I)	1-4	2-8	1	1	7
ES-561 (regenerated) (II)	2-3	1-8	3	1	1
XE-340 (I)	1-4	1-2	7	2	1
XE-340 (regenerated) (II)	2-3	1-3	3		2
HD-1030 7 (II)	1-3	2-4		2	2
HD-1030 8 (II)	1-3	1-3	2	1	1
HD-1030 9 (II)	1-3	1-3	2	1	1
LCK (II)	1-4	1-6	3	2	1
C-THM (II)	1-3	1-12	3		2
ROW 0.8 (II)	1-3	1-17	2	1	3
Sand 13 (II)	1-4	1-4	2	2	2
WVG (steamed) 14 (I)	1-4	1-12	2	3	5
WVG (steamed) 14 (II)	1-2	1-11	2	1	3
ES-561 (steamed) 15 (I)	1-4	2-16	1	1	8
ES-561 (steamed) 15 (II)	1-2	1-3	2	2	2
WVG (virgin) (III & IV)	1-3	1-2	1	4	1
WVG (regenerated) (III & IV)	1-2	1-8	1	1	4
HD-1030 (virgin) (III & IV)	1-4	1-6	1	2	5
HD-1030 (regenerated) (III & IV)	1-4	1-6	1	2	3
XE-340 (regenerated) (III & IV)	1-3	1-3	1	1	4

APPENDICES

APPENDIX A. TRIHALOMETHANE DATA

TABLE A-1. TRIHALOMETHANE CONCENTRATIONS - PHASE I

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
2-16-77	Initial	Influent	3.0	1.0	0.2	0.2
		Column 1	0.2	0.02	0.2	0.2
		Column 2	0.1	ND*	ND	ND
		Column 3	0.1	ND	ND	ND
		Column 4	1.3	0.3	0.3	ND
		Column 5	1.9	0.5	0.3	ND
		Column 6	0.2	ND	ND	ND
2-25-77	9	Influent	16.0	5.1	1.3	ND
		Column 1	ND	ND	ND	ND
		Column 2	ND	ND	ND	ND
		Column 3	ND	ND	ND	ND
		Column 4	14.0	3.8	0.8	ND
		Column 5	11.0	2.8	0.6	ND
		Column 6	0.1	ND	ND	ND
		Column 14	ND	ND	ND	ND
		Column 15	14.0	3.7	0.9	ND
3-1-77	13	Influent	10.0	3.1	1.1	ND
		Column 1	0.1	ND	ND	ND
		Column 2	0.1	ND	ND	ND
		Column 3	0.1	ND	ND	ND
		Column 4	15.0	4.4	1.4	ND
		Column 5	16.0	4.3	1.4	ND
		Column 6	0.2	0.4	ND	ND
		Column 14	0.1	ND	ND	ND
		Column 15	16.0	4.5	1.4	ND
3-10-77	22	Influent	1.5	2.1	1.5	0.09
		Column 1	0.3	0.2	Trace	ND
		Column 2	0.3	0.2	0.01	ND
		Column 3	0.3	0.1	0.01	ND
		Column 4	1.2	3.2	0.7	0.08
		Column 5	1.3	2.5	3.0	Trace
		Column 6	0.4	0.1	0.01	ND
		Column 14	0.3	0.1	0.01	ND
		Column 15	1.0	2.2	1.5	0.1
3-17-77	29	Influent	18.3	2.3	0.4	ND
		Column 1	0.1	ND	ND	ND
		Column 2	0.3	ND	ND	ND
		Column 3	0.2	ND	ND	ND
		Column 4	18.5	2.4	0.5	ND

(continued)

*None detected.

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TABLE A-1. (continued).

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
3-17-77 (contd)	29	Column 5	19.5	ND	ND	ND
		Column 6	0.7	ND	ND	ND
		Column 14	0.3	ND	ND	ND
		Column 15	19.9	2.3	0.1	ND
3-25-77	37	Influent	43.5	3.1	0.4	ND
		Column 1	0.2	ND	ND	ND
		Column 2	0.2	ND	ND	ND
		Column 3	12.3	0.8	0.1	ND
		Column 4	43.5	3.3	0.3	ND
		Column 5	37.0	2.7	ND	ND
		Column 6	0.5	ND	ND	ND
		Column 14	0.2	ND	ND	ND
		Column 15	44.2	3.5	0.4	ND
3-31-77	43	Influent	27.0	7.0	1.6	ND
		Column 1	0.6	ND	ND	ND
		Column 2	0.3	ND	ND	ND
		Column 3	0.2	ND	ND	ND
		Column 4	32.0	6.0	1.3	ND
		Column 5	30.0	5.3	1.2	ND
		Column 6	0.8	0.1	ND	ND
		Column 14	0.5	ND	ND	ND
		Column 15	33.0	5.5	1.2	ND
4-7-77	50	Influent	18.0	3.4	0.8	ND
		Column 1	0.8	ND	ND	ND
		Column 2	0.1	ND	ND	ND
		Column 3	0.1	ND	ND	ND
		Column 4	21.0	4.8	1.0	ND
		Column 5	24.0	4.6	0.9	ND
		Column 6	0.6	0.1	ND	ND
		Column 14	0.6	ND	ND	ND
		Column 15	24.0	4.7	0.8	ND
4-14-77	57	Influent	24.0	4.5	1.1	ND
		Column 1	1.8	ND	ND	ND
		Column 2	0.1	ND	ND	ND
		Column 3	0.1	ND	ND	ND
		Column 4	22.0	4.5	1.1	ND
		Column 5	27.0	5.8	1.4	ND
		Column 6	0.8	0.1	ND	ND
		Column 14	0.9	0.1	ND	ND
		Column 15	25.0	4.9	1.1	ND
4-20-77	63	Influent	34.0	6.8	1.8	ND
		Column 1	3.1	ND	ND	ND
		Column 2	ND	ND	ND	ND
		Column 3	ND	ND	ND	ND
		Column 4	38.0	7.8	2.0	ND
		Column 5	35.0	6.2	1.4	ND
		Column 6	1.1	0.1	ND	ND
		Column 14	1.4	0.1	ND	ND
		Column 15	36.0	6.7	1.6	ND
4-29-77	72	Influent	28.0	4.9	1.0	ND
		Column 1	6.6	0.2	ND	ND
		Column 2	0.2	ND	ND	ND
		Column 3	0.1	ND	ND	ND
		Column 4	34.0	5.0	1.1	ND
		Column 5	35.0	5.3	1.3	ND
		Column 6	0.1	0.1	ND	ND
		Column 14	0.1	0.1	ND	ND
		Column 15	31.0	4.5	1.0	ND

(continued)

TABLE A-1. (continued).

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
5-5-77	78	Influent	34.0	4.5	1.0	ND
		Column 1	0.1	0.2	ND	ND
		Column 2	0.1	ND	ND	ND
		Column 3	ND	ND	ND	ND
		Column 4	36.0	5.3	1.2	ND
		Column 5	34.0	4.8	1.1	ND
		Column 6	0.1	0.1	ND	ND
		Column 14	0.1	0.2	ND	ND
		Column 15	36.0	4.5	1.0	ND
5-13-77	86	Influent	59.0	7.1	0.9	ND
		Column 1	14.0	0.4	ND	ND
		Column 2	0.5	ND	ND	ND
		Column 3	0.5	ND	ND	ND
		Column 4	52.0	5.8	0.9	ND
		Column 5	40.0	4.4	0.9	ND
		Column 6	1.0	ND	ND	ND
		Column 14	6.2	0.3	ND	ND
		Column 15	53.0	6.3	1.1	ND
5-19-77	92	Influent	33.0	7.9	2.1	ND
		Column 1	20.0	0.7	ND	ND
		Column 2	0.5	ND	ND	ND
		Column 3	0.7	0.1	ND	ND
		Column 4	31.0	7.7	1.9	ND
		Column 5	30.0	6.8	1.7	ND
		Column 6	2.2	0.3	ND	ND
		Column 14	9.5	0.4	ND	ND
		Column 15	29.0	6.7	1.6	ND
5-27-77	100	Influent	51.0	11.0	1.7	ND
		Column 1	26.0	1.0	ND	ND
		Column 2	0.4	ND	ND	ND
		Column 3	0.8	ND	ND	ND
		Column 4	44.0	9.9	1.7	ND
		Column 5	47.0	5.8	1.8	ND
		Column 6	1.2	0.1	ND	ND
		Column 14	8.0	2.0	ND	ND
		Column 15	47.0	10.0	1.8	ND
6-1-77	105	Influent	79.2	ND	ND	ND
		Column 1	34.3	1.2	ND	ND
		Column 2	2.7	ND	ND	ND
		Column 3	2.0	0.4	ND	ND
		Column 4	65.9	ND	ND	ND
		Column 5	50.9	8.3	ND	ND
		Column 6	2.0	0.2	ND	ND
		Column 14	12.1	0.8	ND	ND
		Column 15	55.9	ND	ND	ND
6-7-77	111	Influent	11.6	1.9	0.4	ND
		Column 1	13.9	1.4	ND	ND
		Column 2	0.9	ND	ND	ND
		Column 3	0.4	ND	ND	ND
		Column 4	32.5	8.1	1.2	ND
		Column 5	60.9	7.9	2.0	ND
		Column 6	1.1	ND	ND	ND
		Column 14	6.9	0.6	ND	ND
		Column 15	53.3	7.3	1.5	ND

(continued)

TABLE A-1. (continued).

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$ChCl_3$	$ChCl_2Br$	$ChClBr_2$	$CHBr_3$
6-14-77	118	Influent	13.2	2.6	0.7	ND
		Column 1	15.0	1.8	ND	ND
		Column 2	0.9	ND	ND	ND
		Column 3	ND	ND	ND	ND
		Column 4	40.5	8.1	2.0	ND
		Column 5	53.9	8.5	1.5	ND
		Column 6	1.1	0.2	ND	ND
		Column 14	15.7	1.2	ND	ND
		Column 15	44.9	7.9	2.0	ND
6-22-77	126	Influent	42.9	7.1	1.5	ND
		Column 1	38.0	2.8	ND	ND
		Column 2	2.6	ND	ND	ND
		Column 3	0.6	ND	ND	ND
		Column 4	43.2	7.0	1.7	ND
		Column 5	39.0	6.3	1.7	ND
		Column 6	1.3	0.2	ND	ND
		Column 14	8.3	1.0	ND	ND
		Column 15	36.6	6.2	1.7	ND
6-29-77	133	Influent	75.0	8.0	ND	ND
		Column 1	48.0	4.0	ND	ND
		Column 2	4.0	ND	ND	ND
		Column 3	1.0	ND	ND	ND
		Column 4	65.0	8.0	1.0	ND
		Column 5	53.0	9.0	ND	ND
		Column 6	1.0	ND	ND	ND
		Column 14	24.0	1.0	ND	ND
		Column 15	54.0	7.0	1.0	ND
8-18-77	183	Influent	59.3	6.0	0.9	ND
		Column 1	49.6	4.8	0.4	ND
		Column 2	35.2	0.6	0.02	ND
		Column 3	2.2	0.07	0.01	ND
		Column 4	59.3	5.9	1.0	ND
		Column 5	56.8	5.7	1.2	ND
		Column 6	3.0	0.1	0.02	ND
		Column 14	46.2	4.4	0.42	ND
		Column 15	61.2	6.1	1.1	ND

TABLE A-2. TRIHALOMETHANE CONCENTRATIONS - PHASE II

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
8-26-77	Initial	Influent	88.6	30.7	2.5	ND*
		Column 1	1.0	0.2	ND	ND
		Column 2	2.0	0.1	ND	ND
		Column 3	0.4	ND	ND	ND
		Column 4	28.9	3.2	0.3	ND
		Column 5	30.3	3.4	0.4	ND
		Column 6	0.2	ND	ND	ND
		Column 7	0.1	ND	ND	ND
		Column 8	0.4	0.1	ND	ND
		Column 9	1.8	0.1	ND	ND
		Column 10	0.3	ND	ND	ND
		Column 11	0.3	ND	ND	ND
		Column 12	0.2	ND	ND	ND
		Column 13	40.4	14.0	1.0	ND
		Column 14	0.96	ND	ND	ND
		Column 15	22.0	7.0	0.7	ND
8-31-77	5	Influent	66.4	ND	ND	ND
		Column 1	0.2	0.1	ND	ND
		Column 2	ND	ND	ND	ND
		Column 3	0.1	ND	ND	ND
		Column 4	33.2	4.3	1.1	ND
		Column 5	48.6	4.3	1.1	ND
		Column 6	ND	ND	ND	ND
		Column 7	0.1	ND	ND	ND
		Column 8	0.1	ND	ND	ND
		Column 9	0.2	ND	ND	ND
		Column 10	ND	ND	ND	ND
		Column 11	0.1	ND	ND	ND
		Column 12	0.1	ND	ND	ND
		Column 13	66.2	4.3	0.6	ND
		Column 14	0.4	ND	ND	ND
		Column 15	36.5	5.3	1.2	ND
9-7-77	12	Influent	192	17.7	1.6	1.0
		Column 1	0.2	ND	ND	ND
		Column 2	0.5	ND	ND	ND
		Column 3	0.1	ND	ND	ND
		Column 4	81.8	7.9	0.7	ND
		Column 5	127	3.7	0.6	ND
		Column 6	6.6	0.3	0.2	ND
		Column 7	0.4	0.1	0.2	ND
		Column 8	0.8	0.4	0.5	ND
		Column 9	0.4	0.3	0.4	0.5
		Column 10	0.7	0.5	0.3	0.3
		Column 11	0.6	0.2	0.4	0.4
		Column 12	0.1	ND	ND	ND
		Column 13	188	10.6	0.9	ND
		Column 14	0.2	ND	ND	ND
		Column 15	176	7.7	0.4	ND
9-14-77	19	Influent	122	9.3	0.6	ND
		Column 1	0.6	ND	ND	ND
		Column 2	0.7	ND	ND	ND
		Column 3	0.2	ND	ND	ND
		Column 4	115	ND	ND	ND
		Column 5	92.0	7.6	1.4	1.5
		Column 6	8.5	0.5	0.1	ND
		Column 7	0.8	0.1	ND	ND
		Column 8	0.6	ND	ND	ND
		Column 9	0.2	ND	ND	ND

(continued)

*None detected.

TABLE A-2. (continued).

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
9-14-77 (contd)		Column 10	0.6	ND	ND	1.7
		Column 11	0.9	0.1	ND	ND
		Column 12	0.7	ND	ND	ND
		Column 13	122	8.4	0.6	ND
		Column 14	1.3	ND	ND	ND
		Column 15	128	8.6	1.1	ND
9-22-77	27	Influent	119	10.1	2.6	1.7
		Column 1	2.8	0.1	0.1	0.3
		Column 2	0.8	0.1	0.6	ND
		Column 3	4.6	ND	0.1	ND
		Column 4	14.1	9.8	2.0	0.8
		Column 5	148	10.0	1.9	3.8
		Column 6	12.1	0.3	0.1	ND
		Column 7	8.1	0.3	0.1	ND
		Column 8	1.5	0.1	ND	ND
		Column 9	0.4	ND	0.1	ND
		Column 10	2.5	ND	ND	ND
		Column 11	2.9	ND	ND	ND
		Column 12	11.3	ND	0.8	ND
		Column 13	14.1	9.5	2.2	0.5
		Column 14	8.9	0.1	ND	ND
		Column 15	14.8	8.7	1.7	0.5
9-29-77	34	Influent	28.4	9.8	2.1	ND
		Column 1	0.01	ND	ND	ND
		Column 2	0.2	0.03	ND	ND
		Column 3	ND	ND	ND	ND
		Column 4	31.3	9.69	1.3	0.9
		Column 5	36.3	10.0	0.3	0.2
		Column 6	0.01	0.3	ND	ND
		Column 7	0.37	0.17	ND	ND
		Column 8	0.15	0.24	ND	ND
		Column 9	0.70	1.2	ND	ND
		Column 10	0.48	0.40	0.13	ND
		Column 11	1.7	0.11	0.41	ND
		Column 12	1.8	0.24	ND	ND
		Column 13	31.1	10.1	0.35	0.65
		Column 14	2.6	0.16	ND	ND
		Column 15		SAMPLE LOST		
10-10-77	45	Influent	47.0	5.0	0.8	ND
		Column 1	10.6	0.3	0.2	ND
		Column 2	1.3	0.2	ND	ND
		Column 3	1.2	0.7	0.04	ND
		Column 4	53.3	8.7	2.2	1.4
		Column 5	56.8	9.0	1.9	ND
		Column 6	6.6	1.0	0.2	ND
		Column 7	15.0	0.5	0.6	ND
		Column 8	0.6	0.1	0.05	ND
		Column 9	0.9	0.03	ND	ND
		Column 10	3.6	0.03	0.7	ND
		Column 11	6.7	0.2	ND	ND
		Column 12	20.3	0.4	ND	ND
		Column 13	59.9	9.2	1.1	ND
		Column 14	11.5	0.2	0.1	ND
		Column 15	62.4	7.6	1.6	0.9
10-18-77	53	Influent	4.1	0.7	0.1	ND
		Column 1	18.3	0.5	ND	ND
		Column 2	1.1	0.02	ND	ND
		Column 3	0.4	0.02	ND	ND
		Column 4	9.2	1.7	2.2	ND
		Column 5	11.3	2.2	1.6	ND
		Column 6	3.8	0.5	ND	ND

(continued)

TABLE A-2. (continued).

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
10-18-77 (contd)		Column 7	1.2	0.8	0.1	ND
		Column 8	0.4	0.03	0.03	ND
		Column 9	1.4	0.1	1.1	ND
		Column 10	5.4	0.6	0.9	ND
		Column 11	19.2	1.0	3.0	ND
		Column 12	31.4	1.3	0.6	ND
		Column 13	3.8	0.3	0.3	ND
		Column 14	1.4	0.1	1.0	ND
		Column 15	10.6	1.6	2.5	ND
10-24-77	59	Influent	7.4	0.4	0.04	ND
		Column 1	24.9	0.5	ND	ND
		Column 2	1.7	0.6	ND	ND
		Column 3	0.5	0.03	ND	ND
		Column 4	5.1	0.7	0.4	ND
		Column 5	17.9	2.3	8.7	1.2
		Column 6	9.2	2.1	0.8	ND
		Column 7	18.7	0.5	ND	ND
		Column 8	0.2	0.03	ND	ND
		Column 9	0.1	0.05	ND	ND
		Column 10	16.6	ND	ND	ND
		Column 11	7.1	ND	ND	ND
		Column 12	24.0	0.9	ND	ND
		Column 13	8.4	0.1	ND	ND
		Column 14	3.8	0.04	ND	ND
		Column 15	3.9	0.3	0.3	ND
11-1-77	67	Influent	33.2	5.3	1.4	ND
		Column 1	24.2	0.6	0.1	ND
		Column 2	0.7	0.1	ND	ND
		Column 3	0.25	0.02	ND	ND
		Column 4	35.9	4.7	0.5	ND
		Column 5	27.6	1.3	0.1	ND
		Column 6	5.1	0.3	0.05	ND
		Column 7	15.4	0.8	ND	ND
		Column 8	0.7	0.05	ND	ND
		Column 9	0.6	0.04	ND	ND
		Column 10	24.2	0.5	0.04	ND
		Column 11	11.7	0.7	0.1	ND
		Column 12	49.0	1.5	0.1	ND
		Column 13	34.7	4.2	ND	ND
		Column 14	1.7	0.1	ND	ND
		Column 15	32.7	3.0	ND	ND
11-11-77	77	Influent	76.0	9.1	0.4	ND
		Column 1	22.8	0.05	ND	ND
		Column 2	0.6	0.05	ND	ND
		Column 3	0.3	0.03	ND	ND
		Column 4	11.9	0.3	ND	ND
		Column 5	40.0	5.4	1.2	ND
		Column 6	4.4	0.12	ND	ND
		Column 7	21.6	0.8	0.1	ND
		Column 8	1.7	0.1	ND	ND
		Column 9	1.0	0.05	ND	ND
		Column 10	22.5	0.8	0.7	ND
		Column 11	16.0	0.9	0.6	ND
		Column 12	33.7	2.6	0.2	ND
		Column 13	83.0	10.6	1.3	ND
		Column 14	3.6	0.3	ND	ND
		Column 15	41.7	4.2	1.3	ND
11-23-77	89	Influent	21.5	5.4	1.5	ND
		Column 1	15.6	0.7	0.2	ND
		Column 2	1.5	0.3	0.2	ND
		Column 3	1.2	0.3	0.2	ND

(continued)

TABLE A-2. (continued).

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
11-23-77 (contd)		Column 4	21.5	5.1	1.2	ND
		Column 5	21.8	4.8	0.8	ND
		Column 6	4.2	0.3	0.1	ND
		Column 7	12.2	ND	ND	ND
		Column 8	ND	0.1	ND	ND
		Column 9	0.8	ND	ND	ND
		Column 10	18.3	0.4	ND	ND
		Column 11	14.1	0.6	0.1	ND
		Column 12	23.3	1.5	0.1	ND
		Column 13	20.2	4.5	1.2	ND
		Column 14	4.3	0.1	ND	ND
		Column 15	19.6	4.1	1.0	ND
11-30-77	96	Influent	12.5	3.7	1.0	ND
		Column 1	17.4	0.7	ND	ND
		Column 2	0.5	ND	ND	ND
		Column 3	0.4	ND	ND	ND
		Column 4	10.9	3.1	0.9	ND
		Column 5	11.2	3.4	1.0	ND
		Column 6	3.7	0.3	0.1	ND
		Column 7	14.4	0.9	0.1	ND
		Column 8	1.4	0.1	ND	ND
		Column 9	0.7	ND	ND	ND
		Column 10	18.3	0.5	ND	ND
		Column 11	12.2	0.8	0.1	ND
		Column 12	20.7	1.6	0.2	ND
		Column 13	11.7	3.5	1.0	ND
		Column 14	6.1	ND	ND	ND
		Column 15	10.4	3.1	0.9	ND
12-15-77	111	Influent	9.0	3.1	0.9	ND
		Column 1	16.7	0.9	ND	ND
		Column 2	0.4	ND	ND	ND
		Column 3	0.1	ND	ND	ND
		Column 4	10.1	3.5	1.0	ND
		Column 5	10.6	3.6	1.1	ND
		Column 6	3.8	0.2	ND	ND
		Column 7	14.1	1.2	0.1	ND
		Column 8	2.6	ND	ND	ND
		Column 9	0.6	ND	ND	ND
		Column 10	19.4	0.6	ND	ND
		Column 11	11.4	0.9	0.1	ND
		Column 12	16.9	1.6	0.2	ND
		Column 13	9.5	3.3	1.0	ND
		Column 14	7.7	0.4	ND	ND
		Column 15	11.3	3.9	1.2	ND

TABLE A-3. TRIHALOMETHANE CONCENTRATIONS - PHASE III

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
3-29-78	Initial	Influent	2.2	0.5	ND*	ND
		Column 1	ND	ND	ND	ND
		Column 2	ND	ND	ND	ND
		Column 3	0.9	ND	ND	ND
		Column 4	1.9	0.1	ND	ND
		Column 5	0.8	ND	ND	ND
		Column 6	0.7	ND	ND	ND
		Column 7	ND	ND	ND	ND
		Column 8	ND	ND	ND	ND
		Column 9	ND	ND	ND	ND
		Column 10	2.0	ND	ND	ND
		Column 11	0.5	ND	ND	ND
		Column 12	1.0	ND	ND	ND
		Column 13	1.7	0.1	ND	ND
		Column 14	0.4	ND	ND	ND
		Column 15	0.3	ND	ND	ND
4-08-78	10	Influent	1.5	ND	ND	ND
		Column 1	0.6	ND	ND	ND
		Column 2	0.6	ND	ND	ND
		Column 3	0.6	ND	ND	ND
		Column 4	2.7	0.2	ND	ND
		Column 5	10.7	1.7	ND	ND
		Column 6	1.3	ND	ND	ND
		Column 7	0.9	ND	ND	ND
		Column 8	0.6	ND	ND	ND
		Column 9	0.7	ND	ND	ND
		Column 10	4.3	ND	ND	ND
		Column 11	0.6	ND	ND	ND
		Column 12	0.6	ND	ND	ND
		Column 13	1.5	ND	ND	ND
		Column 14	0.9	ND	ND	ND
		Column 15	0.7	ND	ND	ND
4-14-78	16	Influent	72.1	9.7	1.0	ND
		Column 1	0.9	ND	ND	ND
		Column 2	0.7	ND	ND	ND
		Column 3	0.8	ND	ND	ND
		Column 4	3.6	0.4	ND	ND
		Column 5	11.4	0.9	ND	ND
		Column 6	1.0	ND	ND	ND
		Column 7	1.3	ND	ND	ND
		Column 8	1.0	ND	ND	ND
		Column 9	1.2	ND	ND	ND
		Column 10	75.4	4.9	0.2	ND
		Column 11	1.0	ND	ND	ND
		Column 12	1.0	ND	ND	ND
		Column 13	73.2	9.9	1.1	ND
		Column 14	0.9	ND	ND	ND
		Column 15	1.1	ND	ND	ND
4-22-78	24	Influent	1.3	ND	ND	ND
		Column 1	1.0	ND	ND	ND
		Column 2	1.0	ND	ND	ND
		Column 3	0.9	ND	ND	ND
		Column 4	3.3	0.2	ND	ND
		Column 5	6.6	0.5	ND	ND
		Column 6	0.8	ND	ND	ND
		Column 7	1.3	ND	ND	ND
		Column 8	0.9	ND	ND	ND

(continued)

*None detected.

TABLE A-3. (continued).

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
4-22-78 (contd)		Column 9	1.0	ND	ND	ND
		Column 10	14.3	1.5	0.3	ND
		Column 11	1.3	ND	ND	ND
		Column 12	1.7	ND	ND	ND
		Column 13	0.9	ND	ND	ND
		Column 14	0.9	ND	ND	ND
		Column 15	1.1	ND	ND	ND
5-2-78	34	Influent	3.9	0.5	ND	ND
		Column 1	0.8	ND	ND	ND
		Column 2	0.7	ND	ND	ND
		Column 3	0.7	ND	ND	ND
		Column 4	3.3	0.2	ND	ND
		Column 5	11.8	0.4	ND	ND
		Column 6	0.7	ND	ND	ND
		Column 7	1.1	ND	ND	ND
		Column 8	0.6	ND	ND	ND
		Column 9	0.7	ND	ND	ND
		Column 10	6.5	0.4	ND	ND
		Column 11	0.7	ND	ND	ND
		Column 12	1.8	ND	ND	ND
		Column 13	3.5	0.4	ND	ND
		Column 14	ND	ND	ND	ND
		Column 15	2.2	ND	ND	ND
5-15-78	47	Influent	1.8	0.1	ND	ND
		Column 1	0.6	ND	ND	ND
		Column 2	ND	ND	ND	ND
		Column 3	ND	ND	ND	ND
		Column 4	3.6	0.3	ND	ND
		Column 5	4.2	0.3	ND	ND
		Column 6	ND	ND	ND	ND
		Column 7	0.6	ND	ND	ND
		Column 8	ND	ND	ND	ND
		Column 9	ND	ND	ND	ND
		Column 10	2.7	0.2	ND	ND
		Column 11	0.6	ND	ND	ND
		Column 12	1.1	ND	ND	ND
		Column 13	2.1	0.2	ND	ND
		Column 14	ND	ND	ND	ND
		Column 15	1.4	ND	ND	ND
5-22-78	54	Influent	3.9	0.5	ND	ND
		Column 1	0.9	ND	ND	ND
		Column 2	0.1	ND	ND	ND
		Column 3	0.1	ND	ND	ND
		Column 4	3.8	0.3	ND	ND
		Column 5	5.0	0.8	ND	ND
		Column 6	0.3	ND	ND	ND
		Column 7	0.9	ND	ND	ND
		Column 8	0.1	ND	ND	ND
		Column 9	0.1	ND	ND	ND
		Column 10	5.2	0.6	ND	ND
		Column 11	0.7	ND	ND	ND
		Column 12	1.5	ND	ND	ND
		Column 13	4.2	0.5	ND	ND
		Column 14	0.4	ND	ND	ND
		Column 15	1.6	ND	ND	ND
6-2-78	65	Influent	5.2	0.7	ND	ND
		Column 1	1.2	ND	ND	ND
		Column 2	0.3	ND	ND	ND
		Column 3	0.1	ND	ND	ND
		Column 4	4.9	0.5	ND	ND
		Column 5	5.4	0.6	ND	ND

(continued)

TABLE A-3. (continued).

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
6-2-78 (contd)		Column 6	0.3	ND	ND	ND
		Column 7	1.0	ND	ND	ND
		Column 8	0.1	ND	ND	ND
		Column 9	0.1	ND	ND	ND
		Column 10	6.4	0.7	ND	ND
		Column 11	0.9	ND	ND	ND
		Column 12	1.8	ND	ND	ND
		Column 13	5.1	0.6	ND	ND
		Column 14	0.6	ND	ND	ND
		Column 15	1.7	ND	ND	ND

TABLE A-4. TRIHALOMETHANE CONCENTRATIONS - PHASE IV

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
7-19-78	Initial	Influent	58.8	9.6	2.0	ND
		Column 1 T	1.9	0.1	ND	ND
		M	1.8	ND	ND	ND
		B	0.8	ND	ND	ND
		Column 2	0.8	ND	ND	ND
		Column 3	0.8	ND	ND	ND
		Column 4 T	13.9	1.2	0.2	ND
		M	6.3	0.6	0.1	ND
		B	4.4	0.4	0.1	ND
		Column 5	43.3	3.4	0.4	ND
		Column 6 T	2.1	ND	ND	ND
		M	1.1	0.1	ND	ND
		B	0.8	ND	ND	ND
		Column 7 T	1.1	ND	ND	ND
		M	0.9	ND	ND	ND
		B	1.4	ND	ND	ND
		Column 8	2.1	ND	ND	ND
		Column 9	2.1	ND	ND	ND
		Column 10 T	1.0	0.1	ND	ND
		M	0.9	ND	ND	ND
		B	0.8	ND	ND	ND
		Column 11 T	1.0	0.1	ND	ND
		M	0.9	ND	ND	ND
		B	0.8	ND	ND	ND
		Column 12	3.1	0.3	ND	ND
		Column 13	3.6	0.2	ND	ND
		Column 14	1.6	0.1	ND	ND
		Column 15	1.7	0.1	ND	ND
7-24-79	5	Influent	96.4	7.0	0.6	ND
		Column 1 T	81.3	5.7	0.5	ND
		M	ND	ND	ND	ND
		B	ND	ND	ND	ND
		Column 2	ND	ND	ND	ND
		Column 3	ND	ND	ND	ND
		Column 4 T	57.4	4.1	0.5	ND
		M	29.5	2.0	ND	ND
		B	21.3	1.4	ND	ND
		Column 5	35.4	2.9	ND	ND
		Column 6	1.4	ND	ND	ND
		Column 7 T	11.6	0.6	ND	ND
		M	ND	ND	ND	ND
		B	0.6	ND	ND	ND
		Column 8	46.3	3.1	ND	ND
		Column 9	0.7	ND	ND	ND
		Column 10 T	22.5	0.6	ND	ND
		M	ND	ND	ND	ND
		B	ND	ND	ND	ND
		Column 11 T	9.0	ND	ND	ND
		M	ND	ND	ND	ND
		B	ND	ND	ND	ND
		Column 12	0.7	ND	ND	ND
		Column 13	1.0	ND	ND	ND
		Column 14	ND	ND	ND	ND
		Column 15	ND	ND	ND	ND
7-31-78	12	Influent	111.0	19.4	5.9	0.6
		Column 1 T	97.1	8.0	4.8	ND
		M	4.5	ND	ND	ND
		B	ND	ND	ND	ND
		Column 2	ND	ND	ND	ND
		Column 3	ND	ND	ND	ND
		Column 4 T	58.8	10.4	1.2	ND
		M	30.3	6.1	1.1	ND
		B	21.5	5.0	0.9	ND

(continued)

TABLE A-4. (continued).

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
7-31-78 (contd)		Column 5	83.3	9.9	2.6	ND
		Column 6 T	81.0	7.6	3.0	ND
		M	77.7	4.9	0.3	ND
		B	41.8	1.1	ND	ND
		Column 7 T	16.5	1.2	0.8	ND
		M	ND	ND	ND	ND
		B	ND	ND	ND	ND
		Column 8	ND	ND	ND	ND
		Column 9	ND	ND	ND	ND
		Column 10 T	27.9	1.6	ND	ND
		M	0.5	ND	ND	ND
		B	ND	ND	ND	ND
		Column 11 T	21.2	0.9	ND	ND
		M	0.2	ND	ND	ND
		B	ND	ND	ND	ND
		Column 12	0.7	ND	ND	ND
		Column 13	1.1	ND	ND	ND
		Column 14	ND	ND	ND	ND
		Column 15	0.5	ND	ND	ND
8-12-78	24	Influent	27.4	7.5	3.0	ND
		Column 1 T	27.9	7.3	2.3	ND
		M	1.3	ND	ND	ND
		B	ND	ND	ND	ND
		Column 2	ND	ND	ND	ND
		Column 3	ND	ND	ND	ND
		Column 4 T	27.8	4.0	0.9	ND
		M	30.1	5.9	1.7	ND
		B	25.1	3.1	0.6	ND
		Column 5	28.1	4.2	0.9	ND
		Column 6 T	28.9	3.9	0.6	ND
		M	28.4	ND	ND	ND
		B	27.2	1.9	ND	ND
		Column 7 T	27.9	5.5	1.5	ND
		M	4.6	0.3	ND	ND
		B	3.7	0.3	ND	ND
		Column 8	3.9	0.3	ND	ND
		Column 9	5.3	0.5	ND	ND
		Column 10 T	34.3	4.9	0.7	ND
		M	1.4	ND	ND	ND
		B	ND	ND	ND	ND
		Column 11 T	39.3	5.8	0.5	ND
		M	1.2	ND	ND	ND
		B	ND	ND	ND	ND
		Column 12	1.7	ND	ND	ND
		Column 13	4.2	ND	ND	ND
		Column 14	0.8	ND	ND	ND
		Column 15	2.3	ND	ND	ND
8-19-78	31	Influent	26.6	7.5	2.6	ND
		Column 1 T	26.3	6.4	1.8	ND
		M	5.1	ND	ND	ND
		B	ND	ND	ND	ND
		Column 2	ND	ND	ND	ND
		Column 3	ND	ND	ND	ND
		Column 4 T	26.5	5.8	1.6	ND
		M	23.9	3.8	0.8	ND
		B	23.3	3.1	0.6	ND
		Column 5	27.6	4.5	0.9	ND
		Column 6 T	28.2	4.3	0.8	ND
		M	29.3	1.8	ND	ND
		B	28.3	2.6	ND	ND
		Column 7 T	27.9	6.1	1.6	ND
		M	5.5	0.5	ND	ND
		B	Sample Bottle Broken			

(continued)

TABLE A-4. (continued).

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
8-19-78 (contd)		Column 8	1.2	0.2	ND	ND
		Column 9	1.3	ND	ND	ND
		Column 10 T	30.3	5.5	1.0	ND
		M	4.6	ND	ND	ND
		B	1.4	ND	ND	ND
		Column 11 T	31.6	6.6	0.9	ND
		M	4.4	ND	ND	ND
		B	1.0	ND	ND	ND
		Column 12	3.0	ND	ND	ND
		Column 13	8.0	0.2	ND	ND
		Column 14	1.7	ND	ND	ND
		Column 15	2.4	ND	ND	ND
8-27-78	39	Influent	25.2	6.4	2.2	ND
		Column 1 T	22.7	4.3	1.2	ND
		M	11.3	ND	ND	ND
		B	1.7	ND	ND	ND
		Column 2	ND	ND	ND	ND
		Column 3	ND	ND	ND	ND
		Column 4 T	25.2	5.8	1.7	ND
		M	23.6	4.2	0.9	ND
		B	22.3	3.6	0.8	ND
		Column 5	25.0	4.5	1.0	ND
		Column 6 T	24.8	4.2	0.8	ND
		M	26.3	3.5	0.4	ND
		B	28.3	3.4	0.4	ND
		Column 7 T	24.7	5.5	1.6	ND
		M	5.5	0.2	ND	ND
		B	1.6	ND	ND	ND
		Column 8	0.7	ND	ND	ND
		Column 9	1.0	ND	ND	ND
		Column 10 T	28.0	6.0	1.2	ND
		M	10.7	0.3	ND	ND
		B	4.0	ND	ND	ND
		Column 11 T	26.9	6.4	1.2	ND
		M	10.0	ND	ND	ND
		B	3.3	ND	ND	ND
		Column 12	5.1	ND	ND	ND
		Column 13	10.9	0.3	ND	ND
		Column 14	8.6	0.1	ND	ND
		Column 15	1.7	ND	ND	ND
9-3-78	46	Influent	17.4	5.0	1.6	ND
		Column 1 T	17.1	6.3	2.3	ND
		M	13.7	0.3	ND	ND
		B	3.2	ND	ND	ND
		Column 2	0.9	ND	ND	ND
		Column 3	0.9	ND	ND	ND
		Column 4 T	18.6	5.7	1.8	ND
		M	17.8	4.2	1.0	ND
		B	17.4	3.7	0.8	ND
		Column 5	19.0	4.5	1.1	ND
		Column 6 T	20.6	4.7	1.0	ND
		M	20.6	4.0	0.6	ND
		B	20.1	3.5	0.5	ND
		Column 7 T	25.3	6.1	1.8	ND
		M	9.9	0.4	ND	ND
		B	3.1	0.1	ND	ND
		Column 8	1.2	ND	ND	ND
		Column 9	1.7	ND	ND	ND
		Column 10 T	26.5	7.0	3.8	ND
		M	15.4	0.2	ND	ND
		B	7.9	ND	ND	ND
		Column 11 T	24.6	6.9	1.5	ND
		M	16.7	0.?	ND	ND
		B	7.1	0.3	ND	ND

(continued)

TABLE A-4. (continued).

Date	Days of P.P. Operation	Sample	Concentration, ug/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
9-3-78 (contd)		Column 12	8.1	0.2	ND	ND
		Column 13	13.9	0.5	ND	ND
		Column 14	13.8	0.4	ND	ND
		Column 15	2.1	0.1	ND	ND
9-18-78	61	Influent	6.2	0.3	ND	ND
		Column 1 T	8.6	1.7	0.6	ND
		M	18.6	0.6	ND	ND
		B	7.8	0.1	ND	ND
		Column 2	1.6	0.1	ND	ND
		Column 3	1.9	ND	ND	ND
		Column 4 T	15.2	3.2	0.9	ND
		M	16.8	2.4	0.5	ND
		B	16.8	3.1	0.7	ND
		Column 5	18.8	3.3	0.5	ND
		Column 6 T	20.7	3.8	0.8	ND
		M	21.2	0.3	ND	ND
		B	20.8	3.6	0.5	ND
		Column 7 T	11.5	ND	ND	ND
		M	13.4	0.7	ND	ND
		B	7.9	0.3	ND	ND
		Column 8	2.6	0.1	ND	ND
		Column 9	3.0	0.1	ND	ND
		Column 10 T	23.3	4.7	1.1	ND
		M	24.2	0.5	ND	ND
		B	16.5	0.3	ND	ND
		Column 11 T	20.9	3.7	1.1	ND
		M	28.0	0.5	ND	ND
		B	17.1	0.3	ND	ND
		Column 12	12.7	0.4	ND	ND
		Column 13	16.8	0.7	ND	ND
		Column 14	18.6	0.8	ND	ND
		Column 15	2.9	0.2	ND	ND
9-26-78	69	Influent	38.6	5.6	1.4	ND
		Column 1 T	34.4	5.0	1.2	ND
		M	22.9	0.8	ND	ND
		B	11.8	1.0	ND	ND
		Column 2	0.6	ND	ND	ND
		Column 3	0.5	ND	ND	ND
		Column 4 T	27.0	2.9	0.6	ND
		M	22.3	0.6	ND	ND
		B	21.7	2.8	0.5	ND
		Column 5	20.7	2.9	0.6	ND
		Column 6 T	21.5	2.9	0.6	ND
		M	22.3	0.6	ND	ND
		B	21.7	2.8	0.5	ND
		Column 7 T	37.1	5.1	1.2	ND
		M	13.0	0.9	ND	ND
		B	7.4	0.2	ND	ND
		Column 8	0.9	ND	ND	ND
		Column 9	1.5	ND	ND	ND
		Column 10 T	27.8	4.0	1.0	ND
		M	23.5	0.7	ND	ND
		B	17.9	0.3	ND	ND
		Column 11 T	28.4	3.8	1.0	ND
		M	26.2	0.9	ND	ND
		B	18.4	0.2	ND	ND
		Column 12	13.1	0.6	ND	ND
		Column 13	16.9	1.0	ND	ND
		Column 14	17.6	1.0	ND	ND
		Column 15	1.7	ND	ND	ND

(continued)

TABLE A-4. (continued).

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
10-6-78	79	Influent	29.3	5.0	0.4	ND
		Column 1 T	36.1	6.2	0.4	ND
		M	29.1	1.7	ND	ND
		B	19.5	ND	ND	ND
		Column 2	0.7	ND	ND	ND
		Column 3	ND	ND	ND	ND
		Column 4 T	9.1	1.3	ND	ND
		M	5.2	0.8	ND	ND
		B	3.2	0.5	ND	ND
		Column 5	20.2	2.0	ND	ND
		Column 6 T	0.7	0.7	ND	ND
		M	1.0	ND	ND	ND
		B	0.9	ND	ND	ND
		Column 7 T	32.4	5.8	0.5	ND
		M	19.9	2.0	ND	ND
		B	10.4	0.6	ND	ND
		Column 8	0.3	ND	ND	ND
		Column 9	0.2	ND	ND	ND
		Column 10 T	33.6	6.2	0.4	ND
		M	33.0	1.7	ND	ND
		B	24.9	0.8	ND	ND
		Column 11 T	32.7	6.9	0.5	ND
		M	30.4	1.9	ND	ND
		B	25.2	0.7	ND	ND
		Column 12	14.9	0.9	ND	ND
		Column 13	21.2	1.8	ND	ND
		Column 14	21.3	0.8	ND	ND
		Column 15	ND	ND	ND	ND
10-13-78	86	Influent	29.7	6.8	0.3	ND
		Column 1 T	26.4	6.6	0.5	ND
		M	23.4	2.3	ND	ND
		B	19.9	0.4	ND	ND
		Column 2	ND	ND	ND	ND
		Column 3	ND	ND	ND	ND
		Column 4 T	21.0	4.4	ND	ND
		M	ND	ND	ND	ND
		B	9.7	1.6	ND	ND
		Column 5	13.4	3.1	ND	ND
		Column 6 T	9.6	1.2	ND	ND
		M	3.7	ND	ND	ND
		B	3.5	ND	ND	ND
		Column 7 T	26.6	6.6	0.5	ND
		M	21.6	2.3	ND	ND
		B	12.4	0.7	ND	ND
		Column 8	ND	ND	ND	ND
		Column 9	1.0	ND	ND	ND
		Column 10 T	17.1	4.0	0.3	ND
		M	16.1	1.0	ND	ND
		B	17.9	0.7	ND	ND
		Column 11 T	24.6	6.3	0.5	ND
		M	19.6	2.5	ND	ND
		B	18.6	0.5	ND	ND
		Column 12	17.4	1.0	ND	ND
		Column 13	17.2	ND	ND	ND
		Column 14	5.3	ND	ND	ND
		Column 15	0.9	0.1	ND	ND
10-22-78	95	Influent	23.2	4.8	ND	ND
		Column 1 T	23.9	5.5	0.2	ND
		M	35.4	2.9	ND	ND
		B	23.9	0.7	ND	ND
		Column 2	ND	ND	ND	ND
		Column 3	ND	ND	ND	ND

(continued)

TABLE A-4. (continued).

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
10-22-78 (contd)		Column 4 T	23.4	4.4	ND	ND
		M	17.3	2.9	ND	ND
		B	13.8	2.2	ND	ND
		Column 5	16.9	3.1	ND	ND
		Column 6 T	15.6	2.3	ND	ND
		M	11.2	1.1	ND	ND
		B	8.9	0.8	ND	ND
		Column 7 T	23.6	5.0	ND	ND
		M	23.0	2.9	ND	ND
		B	17.7	1.4	ND	ND
		Column 8	1.1	ND	ND	ND
		Column 9	1.3	ND	ND	ND
		Column 10 T	22.4	5.5	0.2	ND
		M	32.4	2.8	ND	ND
		B	29.0	1.7	ND	ND
		Column 11 T	23.6	4.1	ND	ND
		M	33.7	3.3	ND	ND
		B	30.9	1.3	ND	ND
		Column 12	21.1	1.5	ND	ND
		Column 13	27.2	2.8	ND	ND
		Column 14	27.6	2.2	ND	ND
		Column 15	ND	ND	ND	ND
10-29-78	102	Influent	26.7	4.2	1.5	ND
		Column 1 T	25.3	3.9	1.3	ND
		M	23.0	2.3	ND	ND
		B	20.4	1.1	ND	ND
		Column 2	0.7	ND	ND	ND
		Column 3	ND	ND	ND	ND
		Column 4 T	25.0	3.6	ND	ND
		M	19.7	3.0	ND	ND
		B	14.2	2.2	ND	ND
		Column 5	27.0	3.5	ND	ND
		Column 6 T	25.1	2.0	ND	ND
		M	19.3	1.4	ND	ND
		B	12.9	0.9	ND	ND
		Column 7 T	28.0	3.0	ND	ND
		M	24.8	1.7	ND	ND
		B	22.5	1.4	ND	ND
		Column 8	1.3	ND	ND	ND
		Column 9	1.3	ND	ND	ND
		Column 10 T	24.4	3.6	ND	ND
		M	25.8	2.1	ND	ND
		B	24.9	1.4	ND	ND
		Column 11 T	25.7	4.0	ND	ND
		M	28.1	3.2	ND	ND
		B	27.0	1.0	ND	ND
		Column 12	22.6	1.2	ND	ND
		Column 13	25.1	2.3	ND	ND
		Column 14	25.5	2.2	ND	ND
		Column 15	3.7	ND	ND	ND
11-12-78	116	Influent	35.5	5.2	0.9	ND
		Column 1 T	32.0	2.7	0.4	ND
		M	25.8	1.8	ND	ND
		B	20.4	1.1	ND	ND
		Column 2	5.2	1.2	ND	ND
		Column 3	ND	ND	ND	ND
		Column 4 T	25.6	4.5	ND	ND
		M	22.0	2.7	ND	ND
		B	19.2	1.4	ND	ND
		Column 5	35.8	4.2	ND	ND
		Column 6 T	31.5	2.2	ND	ND
		M	24.4	1.7	ND	ND
		B	19.8	1.1	ND	ND

(continued)

TABLE A-4. (continued).

Date	Days of P.P. Operation	Sample	Concentration, µg/l			
			$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
11-12-78 (contd)		Column 7 T	33.6	3.3	ND	ND
		M	27.5	2.2	ND	ND
		B	23.0	1.5	ND	ND
		Column 8	1.2	ND	ND	ND
		Column 9	1.2	ND	ND	ND
		Column 10 T	31.9	3.8	ND	ND
		M	28.2	2.3	ND	ND
		B	24.5	1.2	ND	ND
		Column 11 T	32.8	5.1	ND	ND
		M	29.6	3.9	ND	ND
		B	26.0	2.0	ND	ND
		Column 12	21.7	1.9	ND	ND
		Column 13	22.8	2.8	ND	ND
		Column 14	22.5	2.6	ND	ND
		Column 15	3.0	0.1	ND	ND
11-25-78	129	Influent	41.6	7.1	0.4	ND
		Column 1	20.2	1.5	ND	ND
		Column 2	0.6	ND	ND	ND
		Column 3	0.3	ND	ND	ND
		Column 4	30.4	3.9	0.2	ND
		Column 5	45.2	4.6	ND	ND
		Column 6	27.0	2.4	ND	ND
		Column 7	17.7	1.8	ND	ND
		Column 8	1.2	ND	ND	ND
		Column 9	1.3	ND	ND	ND
		Column 10	24.6	2.5	ND	ND
		Column 11	25.8	2.4	ND	ND
		Column 12	20.6	2.5	ND	ND
		Column 13	22.6	3.0	ND	ND
		Column 14	22.1	2.4	ND	ND
		Column 15	2.6	0.1	ND	ND

APPENDIX B. TOTAL ORGANIC CARBON DATA

TABLE B-1. TOTAL ORGANIC CARBON CONCENTRATIONS - PHASE I

Source	Date and Days of P.P. Operation				
	5-19-77	5-27-77	6-1-77	6-7-77	6-14-77
	92	100	105	111	118
	Total Organic Carbon Concentration, mg/l				
Influent	2.2	3.0	3.2	2.2	2.0
Column 1	1.5	2.0	2.0	1.8	1.2
Column 2	1.4	1.8	1.7	1.4	0.9
Column 3	1.2	1.4	1.1	1.2	0.7
Column 4	2.1	2.0	2.4	2.8	1.7
Column 5	2.3	2.1	2.6	2.8	1.7
Column 6	3.0	2.4	2.1	2.6	1.7
Column 14	---	---	1.9	1.6	1.1
Column 15	---	---	2.9	2.6	1.8
Column 14 (After Steaming)	4.9	1.6	3.4	---	---
Column 15 (After Steaming)	6.0	2.4	7.6	---	---

TABLE B-2. PURGEABLE AND TOTAL ORGANIC CARBON CONCENTRATIONS - PHASE II

Source	Date and Days of P.P. Operation												
	8-26-77	8-31-77	9-7-77	9-14-77	9-22-77	9-29-77	10-10-77	10-18-77	10-24-77	11-11-77	11-23-77	11-30-77	12-8-77
	Initial	5	12	19	27	34	45	53	59	77	89	96	104
Total Organic Carbon Concentration, mg/l													
Influent	2.40	4.27	3.70	3.06	2.09	2.86	2.80	1.81	3.15	2.93	1.71	1.81	2.09
Column 1	1.13	2.19	0.97	1.09	0.94	1.31	1.43	1.18	1.41	1.37	1.19	1.28	1.33
Column 2	1.10	2.12	0.53	0.78	0.64	0.59	0.95	1.11	1.02	0.82	0.69	0.78	0.91
Column 3	1.16	1.90	0.31	0.43	0.51	0.64	0.45	0.60	0.69	0.65	0.73	0.57	0.62
Column 4	2.52	4.27	2.80	3.30	1.79	1.77	2.58	1.97	3.85	2.20	1.84	1.95	1.69
Column 5	3.01	4.43	1.60	2.07	1.80	2.24	2.25	1.87	4.37	2.36	1.93	1.93	1.67
Column 6	2.58	3.32	1.92	1.83	1.91	1.83	2.32	2.14	2.24	2.29	1.88	2.04	1.57
Column 7	0.99	2.76	1.21	1.61	1.46	1.42	1.66	1.54	1.98	1.88	1.68	1.69	1.45
Column 8	1.10	2.46	0.89	1.19	1.12	1.03	1.35	1.27	1.67	1.47	1.30	1.37	1.18
Column 9	1.11	2.27	0.70	1.29	0.89	1.12	0.98	1.06	1.34	1.12	1.53	1.16	0.95
Column 10	0.98	2.35	2.30	1.63	1.48	1.71	1.83	1.79	2.37	2.25	1.57	1.80	1.54
Column 11	1.16	3.09	2.66	2.22	1.72	2.06	2.66	1.76	2.49	2.45	1.60	1.76	1.71
Column 12	0.48	1.59	1.58	1.25	1.15	1.18	1.39	1.58	1.68	1.77	1.53	1.51	1.34
Column 13	2.43	4.22	3.46	3.05	2.12	2.67	2.56	1.84	3.04	3.02	1.68	1.97	1.84
Column 14	0.97	2.10	0.78	0.97	0.91	0.90	1.39	1.17	1.21	1.15	1.06	1.45	1.07
Column 15	2.30	4.32	2.59	3.35	1.66	2.00	2.60	1.84	3.06	2.46	1.82	2.40	1.61
Purgeable Organic Carbon Concentration, µg/l													
Influent	0	0	7	17	10	13	7	9	3	12	5	0	0
Column 1	0	2	1	11	6	21	1	7	7	7	0	10	2
Column 2	0	4	1	10	7	15	7	7	3	4	0	0	0
Column 3	0	2	5	11	7	8	9	11	3	5	0	5	0
Column 4	19	1	6	17	10	10	9	11	48	6	1	2	4
Column 5	22	4	5	11	10	11	11	9	60	6	0	0	4
Column 6	0	4	0	5	8	5	3	9	4	2	0	0	1
Column 7	0	2	5	4	8	2	11	10	7	1	0	0	3
Column 8	1	2	5	6	2	5	6	11	5	0	0	0	5
Column 9	6	2	6	9	3	7	7	10	6	0	0	0	1
Column 10	0	0	0	10	9	10	10	10	6	1	0	3	3
Column 11	0	0	1	10	12	3	27	9	7	0	0	1	3
Column 12	0	0	0	7	8	3	12	10	11	0	1	1	4
Column 13	0	0	5	16	10	8	13	9	10	4	7	2	0
Column 14	0	1	2	7	7	6	7	7	2	0	4	0	0
Column 15	1	1	7	20	10	15	12	10	7	2	4	0	0

TABLE B-3. PURGEABLE AND TOTAL ORGANIC CARBON CONCENTRATIONS - PHASE III

	Date and Days of P.P. Operation							
	3-29-78	4-8-78	4-14-78	4-22-78	5-2-78	5-15-78	5-22-78	6-2-78
Source	Initial	10	16	24	34	47	54	65
Total Organic Carbon Concentration, mg/l								
Influent	3.35	3.00	3.45	2.85	2.82	2.83	3.29	2.79
Column 1	0.33	0.68	0.92	1.12	1.26	1.85	1.70	1.37
Column 2	0.41	0.29	0.44	0.43	0.62	1.19	0.73	1.00
Column 3	0.42	0.37	0.26	0.41	0.38	0.59	0.50	0.79
Column 4	2.86	2.76	3.27	2.74	2.70	2.76	2.77	2.67
Column 5	1.40	1.50	1.98	1.85	2.03	1.82	1.88	1.87
Column 6	0.22	0.65	0.33	0.42	0.63	0.77	0.64	0.65
Column 7	0.36	1.36	1.64	1.75	1.85	2.14	2.00	2.04
Column 8	0.37	0.87	1.04	1.04	1.33	1.96	1.50	1.28
Column 9	0.26	0.70	0.90	0.77	1.06	1.51	1.12	1.24
Column 10	2.14	1.54	1.82	1.49	1.63	1.51	1.51	1.50
Column 11	0.29	0.66	0.99	1.04	1.23	1.62	1.57	1.43
Column 12	0.17	1.50	1.92	1.79	1.94	2.14	2.23	2.13
Column 13	3.25	2.97	3.40	2.78	2.64	2.77	3.22	2.83
Column 14	0.46	1.84	2.33	2.32	1.96	2.31	2.26	2.17
Column 15	0.27	0.47	0.88	0.89	1.15	1.60	1.50	1.58
Purgeable Organic Carbon Concentration, µg/l								
Influent	3	3	8	5	3	4	9	1
Column 1	1	6	0	2	2	5	1	0
Column 2	2	4	0	1	2	3	0	1
Column 3	3	6	0	4	3	4	0	0
Column 4	5	6	1	4	3	4	5	1
Column 5	5	7	1	2	35	5	2	1
Column 6	2	6	1	5	4	5	2	1
Column 7	0	6	3	2	3	3	1	0
Column 8	0	4	4	0	3	2	0	0
Column 9	0	4	0	0	3	2	0	0
Column 10	5	8	10	4	5	3	5	0
Column 11	3	9	2	3	5	4	6	1
Column 12	0	6	0	0	3	3	4	1
Column 13	0	8	9	7	7	2	17	2
Column 14	0	5	0	2	4	1	3	1
Column 15	0	8	2	0	6	5	2	3

TABLE B-4. PURGEABLE AND TOTAL ORGANIC CARBON CONCENTRATIONS - PHASE IV

Source	Date and Days of P.P. Operation														
	7-19-78	7-24-78	7-31-78	8-12-78	8-19-78	8-27-78	9-3-78	9-18-78	9-26-78	10-6-78	10-13-78	10-22-78	10-29-78	11-12-78	11-25-78
	Initial	5	12	24	31	39	46	61	69	79	86	95	102	116	129
Total Organic Carbon Concentration, mg/l															
Influent	2.27	2.52	2.21	1.83	1.70	1.87	1.85	2.74	3.47	1.76	1.76	1.75	2.03	2.11	1.99
Column 1	0.093	0.11	0.78	0.72	0.76	0.82	0.83	0.81	1.22	0.91	0.84	1.04	1.64	1.56	1.30
Column 2	0.087	0.10	0.48	0.62	0.46	0.60	0.59	0.61	0.74	0.59	0.57	0.72	1.02	0.94	0.78
Column 3	0.070	0.07	0.24	0.48	0.35	0.38	0.42	0.43	0.55	0.49	0.45	0.48	0.82	0.72	0.62
Column 4	2.01	2.14	1.85	1.99	1.79	1.85	1.73	2.18	3.46	1.84	1.83	1.71	1.89	2.02	1.92
Column 5	0.99	1.22	1.58	1.78	1.76	1.72	1.68	2.29	3.54	1.38	2.64	1.66	1.66	1.98	1.90
Column 6	0.078	0.65	1.13	1.32	1.27	1.34	1.34	1.49	2.48	1.08	1.01	1.42	1.62	1.70	1.85
Column 7	0.64	0.76	0.82	1.13	1.04	1.28	1.18	1.26	1.97	1.31	1.27	1.44	1.64	1.65	1.64
Column 8	0.17	0.71	0.62	1.01	0.93	1.07	0.94	1.00	1.44	1.08	0.97	1.17	1.34	1.38	1.32
Column 9	0.16	0.69	0.46	0.77	0.76	0.97	0.93	0.96	1.01	0.84	0.89	1.01	1.15	1.15	1.12
Column 10	0.13	0.19	0.73	0.87	0.80	0.96	0.86	1.00	1.28	0.96	0.97	1.18	1.24	1.33	1.45
Column 11	0.087	0.18	0.70	0.80	0.76	1.40	0.82	0.90	1.20	0.90	0.94	1.07	1.17	1.21	1.29
Column 12	0.21	1.07	0.72	1.17	1.06	1.33	1.26	1.37	1.74	1.27	1.33	1.39	1.63	1.66	1.64
Column 13	0.057	1.17	0.78	1.22	1.13	1.40	1.31	1.41	1.93	1.30	1.43	1.48	1.64	1.70	1.75
Column 14	0.26	0.48	0.88	0.80	0.80	0.92	0.84	0.96	1.14	1.14	1.08	1.09	1.36	1.32	1.32
Column 15	0.26	0.31	0.83	0.79	0.60	0.76	0.75	0.85	0.97	0.71	0.70	0.81	0.97	0.99	1.04
Purgeable Organic Carbon Concentration, µg/l															
Influent	38	26	22	8	13	11	9	25	35	13	12	6	6	7	9
Column 1	10	13	59	4	6	6	2	11	4	11	10	5	6	6	6
Column 2	11	20	18	5	6	7	3	7	3	9	7	3	4	6	4
Column 3	14	14	20	9	6	8	4	15	4	10	9	4	4	4	4
Column 4	15	20	52	12	16	10	6	15	27	13	13	5	6	7	6
Column 5	28	22	23	7	15	13	6	25	11	15	30	4	9	8	6
Column 6	22	17	38	7	14	5	7	14	20	11	9	4	7	6	6
Column 7	22	16	52	4	10	6	4	15	3	4	9	5	3	3	2
Column 8	17	20	4	4	8	6	2	13	6	4	7	3	4	3	1
Column 9	15	14	5	5	7	5	3	11	0	9	9	5	4	4	1
Column 10	9	12	36	5	37	6	4	12	4	11	13	7	6	6	3
Column 11	15	9	38	7	14	13	6	16	3	12	14	6	5	5	3
Column 12	17	10	5	4	7	9	4	12	2	9	14	6	4	5	3
Column 13	11	13	4	2	47	8	5	12	8	10	10	7	4	6	3
Column 14	45	20	31	6	18	8	9	11	3	9	12	6	4	7	2
Column 15	39	25	49	3	7	5	3	11	4	5	10	6	2	4	3

APPENDIX C. THRESHOLD ODOR NUMBER DATA

TABLE C-1. THRESHOLD ODOR NUMBER RESULTS - PHASE I

Date (and Days of P.P. Operation)	Sample	Influent TON	Character	Column Effluent TON	Character*
3-1-77 (13)	Column 1	4	M	1	No Odor
3-8-77 (20)		2	M	1	M
5-11-77 (84)		1	M	1	M
5-18-77 (91)		3	M	2	C, Ch, M
5-25-77 (98)		3	M	2	M
6-3-77 (107)		2	M	2	Ch, M
6-8-77 (112)		3	M	2	M
6-15-77 (119)		2	M	2	C, Ch
6-22-77 (126)		2	M	1	M
6-29-77 (133)		1	M	1	M
3-1-77 (13)	Column 2	4	M	1	Ch
3-8-77 (20)		2	M	2	Ch
5-11-77 (84)		1	M	1	Ch
5-18-77 (91)		3	M	Not Examined	
5-25-77 (98)		3	M	1	C, Ch, M
6-3-77 (107)		2	M	2	C, Ch, M
6-8-77 (112)		3	M	2	Ch, M
6-15-77 (119)		2	M	6	C, Ch, M
6-22-77 (126)		2	M	2	Ch, M
6-29-77 (133)		1	M	Not Examined	
3-1-77 (13)	Column 3	4	M	1	D, M
3-8-77 (20)		2	M	1	Ch
5-11-77 (84)		1	M	1	No Odor
5-18-77 (91)		3	M	1	M
5-25-77 (98)		3	M	1	M
6-3-77 (107)		2	M	1	No Odor
6-8-77 (112)		3	M	2	M
6-15-77 (119)		2	M	1	M
6-22-77 (126)		2	M	1	Bs, M
6-29-77 (133)		1	M	1	C, M
3-1-77 (13)	Column 4	4	M	2	Bs, Ch, Mm
3-8-77 (20)		2	M	6	Ch
5-11-77 (84)		1	M	3	M
5-18-77 (91)		3	M	3	C, Ch, Mm
5-25-77 (98)		3	M	4	M
6-3-77 (107)		2	M	4	A, C, E
6-8-77 (112)		3	M	2	C
6-15-77 (119)		2	M	2	C, E, Mm
6-22-77 (126)		2	M	2	C, M
6-29-77 (133)		1	M	3	C, E
3-1-77 (13)	Column 5	4	M	2	V
3-8-77 (20)		2	M	3	Ch, Cm, D
5-11-77 (84)		1	M	3	C
5-18-77 (91)		3	M	6	Ch, Cm, M
5-25-77 (98)		3	M	8	M
6-3-77 (107)		2	M	3	A, C, E
6-8-77 (112)		3	M	3	C
6-15-77 (119)		2	M	6	C
6-22-77 (126)		2	M	3	C, M
6-29-77 (133)		1	M	3	C
3-1-77 (13)	Column 6	4	M	1	No Odor
3-8-77 (20)		2	M	1	M
5-11-77 (84)		1	M	1	M
5-18-77 (91)		3	M	2	M

(continued)

*See footnote at end of Table C-4 for abbreviation key.

TABLE C-1. (continued).

Date (and Days of P.P. Operation)	Sample	Influent TON	Character	Column Effluent TON	Character
5-25-77 (98)	Column 6	3	M	1	No Odor
6-3-77 (107)	(continued)	2	M	1	M
6-8-77 (112)		3	M	1	M
6-15-77 (119)		2	M	2	M, Mm
6-22-77 (126)		2	M	1	M
6-29-77 (133)		1	M	2	M
3-1-77 (13)	Column 14	4	M	1	No Odor
3-8-77 (20)		2	M	3	C, Ch, D
5-11-77 (84)		1	M	6	C, Ch, M
5-18-77 (91)		3	M	12	Ch
5-25-77 (98)		3	M	2	M
6-3-77 (107)		2	M	6	Ch
6-8-77 (112)		3	M	3	M
6-15-77 (119)		2	M	2	M
6-22-77 (126)		2	M	2	Ch, M, Mm
6-29-77 (133)		1	M	3	M
3-1-77 (13)	Column 15	4	M	2	Ch, M, Mm
3-8-77 (20)		2	M	16	A
5-11-77 (84)		1	M	2	C, E, M
5-18-77 (91)		3	M	16	Ch
5-25-77 (98)		3	M	4	A, Ch, M
6-3-77 (107)		2	M	12	A, C, Ch
6-8-77 (112)		3	M	3	C, D, M
6-15-77 (119)		2	M	12	M
6-22-77 (126)		2	M	4	C
6-29-77 (133)		1	M	2	M

TABLE C-2. THRESHOLD ODOR NUMBER RESULTS - PHASE II

Date (and Days of P.P. Operation)	Sample	Influent TON	Character	Column Effluent TON	Character*
9-29-77 (34)	Column 1	1	M	8	Ds, E, M
10-13-77 (48)		3	M	2	C, E, M
10-27-77 (62)		3	C, E	2	Ch, M, Mm
11-10-77 (76)		3	E	1	M
12-8-77 (104)		1	M	2	M
9-29-77 (34)	Column 2	1	M	12	C, E, M
10-13-77 (48)		3	M	1	Mm
10-27-77 (62)		3	C, E	6	M, Mm
11-10-77 (76)		3	E	2	M
12-8-77 (104)		1	M	3	Ch, M, Mm
9-29-77 (34)	Column 3	1	M	6	Ch, E, M
10-13-77 (48)		3	M	1	M
10-27-77 (62)		3	C, E	2	M
11-10-77 (76)		3	E	2	M
12-8-77 (104)		1	M	1	E, M
10-6-77 (41)	Column 4	2	M	4	E
10-20-77 (55)		2	E, M	2	Ch, M, Mm
11-3-77 (69)		3	M	2	C
11-17-77 (83)		2	M	2	C
12-1-77 (97)		2	M	2	A, C, M
10-6-77 (41)	Column 5	2	M	8	M
10-20-77 (55)		2	E, M	1	C, Ch, M
11-3-77 (69)		3	M	2	C, Mm, V
11-17-77 (83)		2	M	1	E, Mm
12-1-77 (97)		2	M	2	M
10-6-77 (41)	Column 6	2	M	3	M
10-20-77 (55)		2	E, M	3	A, C, M
11-3-77 (69)		3	M	2	C, D, Mm
11-17-77 (83)		2	M	1	Ds
12-1-77 (97)		2	M	1	No Odor
9-30-77 (35)	Column 7	3	M	4	Ch
10-14-77 (49)		1	M	3	Ch
10-28-77 (63)		2	M	2	C
12-9-77 (105)		3	M	3	M
9-30-77 (35)	Column 8	3	M	3	Ch, M
10-14-77 (49)		1	M	2	M
10-28-77 (63)		2	M	1	M
12-9-77 (105)		3	M	2	M
9-30-77 (35)	Column 9	3	M	3	M
10-14-77 (49)		1	M	2	C
10-28-77 (63)		2	M	1	M
12-9-77 (105)		3	M	2	M
9-29-77 (34)	Column 10	3	A	2	C, Ch, V
10-11-77 (46)		3	M	3	M
10-25-77 (60)		4	C	6	Ch
11-8-77 (74)		2	M	1	C
11-22-77 (88)		2	M	1	Ch, M
12-6-77 (102)		1	M	1	M

(continued)

*See footnote at end of Table C-4 for abbreviation key.

TABLE C-2. (continued).

Date (and Days of P.P. Operation)	Sample	Influent TON	Character	Column Effluent TON	Character
10-4-77 (39)	Column 11	2	C, M	12	B, E, M
10-18-77 (53)		1	M	2	M
11-1-77 (67)		3	M	1	Ch, M, V
11-15-77 (81)		2	C	1	C, Mm
11-29-77 (95)		2	M	1	Ch
9-28-77 (33)	Column 12	2	M	17	C, Ch, E
10-12-77 (47)		3	M	2	Ch
10-26-77 (61)		3	Bm, C, Cm, Df, M	1	M
11-9-77 (75)		3	M	3	C
11-23-77 (89)		2	M	3	M
12-7-77 (103)		1	M	3	Cm, M, Mm
10-5-77 (40)	Column 13	3	M	4	M
10-19-77 (54)		2	M	2	C, M, Mm
11-2-77 (68)		4	A, C, Cc, E, Mm	2	A, C, M
11-16-77 (82)		2	M	1	M
11-30-77 (96)		1	M	1	A, C, M
12-14-77 (110)		2	M	3	M
10-7-77 (42)	Column 14	2	M	11	M
10-21-77 (56)		1	C, M	3	M
11-4-77 (70)		2	M	2	C, E, M
11-18-77 (84)		1	M	3	M
12-2-77 (98)		2	M	1	No Odor
12-16-77 (112)		2	M	1	M
10-7-77 (42)	Column 15	2	M	1	A, C
10-21-77 (56)		1	C, M	1	M, Mm
11-4-77 (70)		2	M	3	C
11-18-77 (84)		1	M	2	M
12-2-77 (98)		2	M	2	M
12-16-77 (112)		2	M	1	M

TABLE C-3. THRESHOLD ODOR NUMBER RESULTS - PHASE III

Date (and Days of P.P. Operation)	Sample	Influent TON	Character	Column Effluent TON	Character*
6-6-78 (69)	Column 4			3	M
6-6-78 (69)	Column 5			8	Df
6-6-78 (69)	Column 6			2	M
5-31-78 (63)	Column 7			3	M
5-31-78 (63)	Column 8			3	M
5-31-78 (63)	Column 9			1	M
6-1-78 (64)	Column 10			2	M
6-1-78 (64)	Column 11			2	M
6-1-78 (64)	Column 12			1	M
6-9-78 (72)				6	C
6-2-78 (65)	Column 13			4	M
6-2-78 (65)	Column 14			6	M
6-9-78 (72)				6	M
6-2-78 (65)	Column 15			3	M
6-9-78 (72)				6	C, CM, M

*See footnote at end of Table C-4 for abbreviation key.

TABLE C-4. THRESHOLD ODOR NUMBER RESULTS - PHASE IV

Date (and Days of P.P. Operation)	Sample	Influent TON	Character	Column Effluent TON	Character*
7-24-78 (5)	Column 1			1	C
7-31-78 (12)				2	M
8-7-78 (19)				4•	Bs, Ds, M
8-14-78 (26)				1	M
8-28-78 (40)				8	D, Dp, M
9-11-78 (54)				2	M
7-24-78 (5)	Column 2			1	B
7-31-78 (12)				1	E
8-7-78 (19)				2	C, Ds, M
8-14-78 (26)				2	C, M
8-28-78 (40)				2	Ch, M
9-11-78 (54)				2	D, E, M
7-24-78 (5)	Column 3			2	C, Ch
7-31-78 (12)				3	M
8-7-78 (19)				8	M
8-14-78 (26)				1	C
8-28-78 (40)				3	Ch, G, M
9-11-78 (54)				2	D, E, M
7-25-78 (6)	Column 4			2	M
8-1-78 (13)				2	Ch, G, M
8-8-78 (20)				3	M
8-15-78 (27)				1	Ep, M
8-29-78 (41)				1.4	Ch, M
9-12-78 (55)				2	M, Mm
7-25-78 (6)	Column 5			3	C, Df, M
8-1-78 (13)				6	Ch
8-8-78 (20)				6	C, Df, Ds
8-15-78 (27)				4	Df
8-29-78 (41)				2	M
9-12-78 (55)				8	Ch, Df, Dp
7-25-78 (6)	Column 6			2	Ds
8-1-78 (13)				3	Ch
8-8-78 (20)				6	C, Df, M
8-15-78 (27)				4	Df
8-29-78 (41)					Df
9-12-78 (55)				4	Df
7-26-78 (7)	Column 7			6	M
8-2-78 (14)				3	C, Cs, Dp
8-9-78 (21)				1	Ds, E
8-16-78 (28)				4	E
8-30-78 (42)				1	Cc
9-13-78 (56)				1	M
7-26-78 (7)	Column 8			2	M
8-2-78 (14)				1	E
8-9-78 (78)				3	Bg, G, M
8-16-78 (28)				1.4	Bs, M
8-30-78 (42)				3	Bs, E, Mm
9-13-78 (56)				1	D, M
7-26-78 (7)	Column 9			1.4	Ch
8-2-78 (14)				2	C, E
8-9-78 (21)				3	Bs, Cm, M
8-16-78 (28)				0	---
8-30-78 (42)				2	Bs, M, M
9-13-78 (56)				1	E, M

(continued)

*See footnote at end of this table for abbreviation key.

TABLE C-4. (continued).

Date (and Days of P.P. Operation)	Sample	Influent TON	Character	Column Effluent TON	Character
7-27-78 (8)	Column 10			2	D, M, Mm
8-3-78 (14)				2	M
8-10-78 (22)				1	C
8-17-78 (29)				2	E, G
8-24-78 (36)				3	C, E, M
9-7-78 (50)				2	C, E, M
9-14-78 (57)				1	E, V
7-27-78 (8)	Column 11			2	Cs, D, G
8-3-78 (15)				1	M
8-10-78 (22)				1	M
8-17-78 (29)				1	M
8-24-78 (36)				Sample was bad	
9-7-78 (50)					E, V, V
9-14-78 (57)				1	C, E
7-27-78 (8)	Column 12			1	D, Ds, M
8-3-78 (15)				3	M
8-10-78 (22)				1	C
8-17-78 (29)				6	E, M
9-1-78 (44)				2	Dp, M
9-7-78 (50)				6	C, V, V
9-14-78 (57)				3	A, E, M
7-27-78 (8)	Column 13			1	M
8-3-78 (15)				4	M
8-10-78 (22)				1	M
8-17-78 (29)				2	Ds, M
9-1-78 (44)				3+	M
9-7-78 (50)				6	C, V, V
9-14-78 (57)				3	A, E, M
7-28-78 (9)	Column 14			2	M
8-4-78 (16)				1	M
8-10-78 (22)				3	M
8-18-78 (30)				2	A, E, M
8-25-78 (37)				3	M
9-8-78 (51)				1	M
7-28-78 (9)	Column 15			2	Df, Ds, Mm
8-4-78 (16)				2	Bs, C, M
8-10-78 (22)				0	C, M, Mm
8-18-78 (30)				2	A, M, V
8-25-78 (37)				4+	M
9-8-78 (51)				2	D, M

*Character Key:

A - Aromatic	D - Disagreeable
B - Balsamy	Df - Disagreeable-fishy
Bs - Balsamy-sweet	Ds - Disagreeable-septic
C - Chemical	E - Earthy
Cc - Chemical-chlorinous	M - Musty
Ch - Chemical-hydrocarbon	Mm - Musty-moldy
Cm - Chemical-metallic	V - Vegetable

APPENDIX D. CHEMICAL PARAMETERS

TABLE D-1. KANSAS CITY TREATMENT PLANT LABORATORY DATA--TURBIDITY, COLOR, TON, AND WATER TEMPERATURE

Date	TTHM µg/l	Turbidity			Color			Threshold Odor Number			Water Temperature °F at 7 AM
		River	Raw	Delivered	River	Raw	Delivered	River	Raw	Delivered	
2-15-77		25	25	0.09	1	1	0	6	5	1	33
2-16-77	4	30	25	0.08	1	1	0	6	4	1	33
2-24-77		205	190	0.07	2	2	0	7	7	1	33
2-25-77	22	150	135	0.10	3	3	2	8	7	2	34
2-28-77		125	140	0.08	2	2	1	8	7	1	33
3-1-77	14	130	150	0.10	2	2	0	7	6	1	35
3-9-77		80	80	0.10	3	3	0	7	6	1	38
3-10-77	5	100	95	0.05	2	2	0	6	6	1	38
3-16-77		210	220	0.10	2	2	0	8	8	1	48
3-17-77	21	230	235	0.07	2	2	0	8	8	1	50
3-24-77		185	160	0.06	3	3	1	9	7	1	48
3-25-77	47	150	140	0.10	2	2	1	7	7	1	46
3-30-77		210	185	0.08	5	5	1	7	6	1	49
3-31-77	36	185	180	0.15	4	4	1	7	6	1	49
4-6-77		120	115	0.10	3	3	1	6	6	1	46
4-7-77	22	165	165	0.06	3	3	1	6	6	1	46
4-13-77		120	110	0.07	3	3	1	7	6	1	54
4-14-77	30	110	100	0.07	3	3	1	6	6	1	56
4-19-77		130	130	0.06	3	3	1	6	6	1	61
4-20-77	43	175	155	0.07	4	3	1	8	6	1	61
4-28-77		180	150	0.08	3	2	1	7	6	1	62
4-29-77	34	145	125	0.10	3	2	1	6	6	1	62
5-4-77		125	100	0.09	2	2	1	7	6	1	63
5-5-77	40	115	90	0.08	3	3	1	7	6	1	65
5-12-77		825	720	0.09	3	2	1	9	7	1	67
5-13-77	67	585	470	0.13	5	5	1	8	8	1	67
5-18-77		200	190	0.12	5	5	1	7	6	1	70
5-19-77	43	255	225	0.11	4	3	1	7	7	1	72
5-26-77		1655	1390	0.08	15	10	1	12	11	1	71
5-27-77	64	1400	1225	0.09	25	20	2	12	12	1	73
5-31-77		2085	1850	0.08	7	7	0	11	8	1	73
6-1-77	80	1850	1530	0.06	15	10	1	12	8	1	73
6-6-77		400	340	0.17	5	5	1	8	8	1	76
6-7-77	14	310	320	0.07	5	5	1	8	7	1	77
6-13-77		120	115	0.09	5	5	1	8	8	1	76
6-14-77	17	125	110	0.09	5	5	1	8	6	1	75
6-21-77		245	215	0.11	5	5	1	7	7	1	78
6-22-77	52	1360	1130	0.12	8	6	1	11	9	1	76
6-28-77		2200	2000	0.13	17	15	1	12	12	1	80
6-29-77	83	2800	2700	0.12	25	25	1	12	12	1	79
8-17-77		1300	1365	0.07	13	13	1	11	8	1	80
8-18-77	66	1550	1425	0.07	13	13	1	9	8	1	80
8-25-77		565	455	0.11	10	10	1	8	8	1	77
8-26-77	122	510	500	0.06	15	17	1	7	7	1	75
8-30-77		2250	2275	0.07	20	20	1	12	12	1	74
8-31-77	66	1115	970	0.08	18	18	1	9	9	1	75
9-6-77		2115	2075	0.08	20	20	1	12	12	1	74
9-7-77	212	1910	1925	0.08	20	20	1	12	12	1	75
9-13-77		2900	2835	0.10	20	17	1	12	12	1	71
9-14-77	132	2785	2730	0.13	20	18	1	12	12	1	69
9-21-77		595	550	0.04	20	22	0	9	8	1	72
9-22-77	133	350	335	0.02	18	20	1	8	8	2	71
9-28-77		495	470	0.02	18	20	1	8	8	1	67
9-29-77	40	260	250	0.04	23	23	1	12	12	1	67
10-9-77		610	565	0.06	15	15	0	8	6	1	58
10-10-77	53	590	665	0.08	12	13	1	8	8	1	58
10-17-77		105	100	0.07	7	7	1	6	6	1	55
10-18-77	5	125	110	0.09	8	8	0	6	6	1	55
10-23-77		1250	1100	0.12	15	15	1	12	8	1	55
10-24-77	8	760	840	0.05	15	17	1	6	6	1	56
10-31-77		360	250	0.03	12	12	1	6	6	1	56

(continued)

TABLE D-1. (continued).

Date	TTHM	Turbidity			Color			Threshold Odor Number			Water Temperature
	µg/l	River	Raw	Delivered	River	Raw	Delivered	River	Raw	Delivered	°F at 7 AM
11-1-77	40	1600	1400	0.09	13	12	1	8	8	1	57
11-10-77		2025	2135	0.05	18	18	1	8	8	1	48
11-11-77	86	1450	1450	0.06	20	20	1	12	8	1	48
11-22-77		160	160	0.06	8	8	0	8	8	1	45
11-23-77	28	140	150	0.04	5	5	1	6	6	1	44
11-29-77		125	135	0.04	5	5	0	6	6	1	34
11-30-77	27	100	120	0.03	4	4	1	6	6	1	36
12-14-77		75	85	0.03	4	4	1	6	6	1	34
12-15-77	13	75	75	0.05	5	5	1	6	6	1	34
3-28-78		730	820	0.05	10	10	1	8	8	2	41
3-29-78	3	550	535	0.20	10	10	1	8	8	2	43
4-7-78		355	295	0.29	13	12	2	8	8	3	54
4-8-78	2	320	260	0.21	12	12	0	8	8	3	54
4-13-78		1935	1865	0.09	18	18	0	8	8	2	55
4-14-78	+83	855	870	0.12	20	20	1	8	8	3	54
4-21-78		1360	1310	0.15	17	15	1	8	8	3	54
4-22-78	1	1150	1175	0.19	10	10	0	8	8	2	54
5-1-78		300	335	0.06	15	15	0	6	6	2	55
5-2-78	4	255	225	0.10	12	12	0	6	6	1	53
5-14-78		735	960	0.05	15	15	1	12	12	1	58
5-15-78	2	530	545	0.13	15	15	0	8	8	1	61
5-21-78		835	925	0.06	20	20	0	6	6	2	64
5-22-78	4	1600	1870	0.10	20	20	1	8	8	3	65
6-1-78		3400	3375	0.06	15	15	0	12	8	3	73
6-2-78	6	2335	2325	0.05	13	13	0	12	12	8	71
7-18-78		360	350	0.04	15	15	0	6	6	2	79
7-19-78	70	235	235	0.04	15	15	0	8	6	4	81
7-23-78		3035	2720	0.04	25	25	0	12	8	2	82
7-24-78	104	2425	2270	0.06	25	25	0	12	8	2	78
7-30-78		235	235	0.04	15	15	0	6	6	1	79
7-31-78	137	205	220	0.05	15	15	0	6	6	1	79
8-11-78		135	120	0.04	7	7	0	4	4	1	76
8-12-78	38	195	210	0.03	7	7	0	6	4	1	77
8-18-78		125	145	0.03	5	5	0	4	4	1	81
8-19-78	37	115	120	0.04	8	8	0	4	4	1	81
8-26-78		130	125	0.04	12	12	0	6	6	1	79
8-27-78	34	105	105	0.05	10	10	0	6	6	1	78
9-2-78		100	90	0.04	10	10	0	6	6	1	77
9-3-78	24	95	90	0.06	10	10	0	8	6	1	78
9-17-78		1835	1835	0.11	25	25	1	12	8	1	78
9-18-78	7	1690	1770	0.06	30	30	1	10	8	1	75
9-25-78		295	310	0.06	15	15	1	8	6	1	68
9-26-78	46	185	180	0.05	5	5	0	6	6	1	68
10-5-78		95	90	0.06	10	10	1	6	6	1	64
10-6-78	35	105	95	0.06	10	10	1	6	6	1	64
10-12-78		110	115	0.06	10	10	1	6	6	1	60
10-13-78	37	105	95	0.05	10	10	1	6	6	1	57
10-21-78		95	95	0.05	10	10	0	6	6	1	57
10-22-78	28	95	95	0.07	10	10	0	6	6	1	57
10-28-78		85	85	0.06	10	10	0	6	6	1	55
10-29-78	32	90	95	0.06	10	10	1	6	6	1	52
11-11-78		80	80	0.06	10	10	1	6	6	1	54
11-12-78	42	120	95	0.07	10	10	1	6	6	1	52
11-24-78		105	100	0.05	8	8	1	6	6	1	39
11-25-78	49	115	105	0.08	10	10	1	6	6	1	39

TABLE D-2. KANSAS CITY TREATMENT PLANT LABORATORY DATA--RESIDUAL CHLORINE, AMMONIA, AND DISSOLVED OXYGEN

Date	TTHM µg/l	Residual Chlorine, mg/l			Ammonia, mg/l			Dissolved Oxygen, mg/l		
		Settled Water								
		Secondary	Final	Delivered	River	Raw	Delivered	River	Raw	Delivered
2-15-77		0.80	0.94	1.06	0.49	0.47	0.52	11.6	10.5	12.7
2-16-77	4	0.93	0.92	1.14	0.57	0.58	0.50	11.8	10.5	12.3
2-24-77		0.79	0.75	1.00	0.29	0.43	0.42			
2-25-77	22	0.90	0.86	1.13	0.47	0.50	0.40			
2-28-77		0.74	0.70	1.00	0.60	0.61	0.40			
3-1-77	14	0.90	0.82	1.05	0.49	0.52	0.44	11.0	11.5	12.5
3-9-77		1.01	1.16	1.04	0.22	0.22	0.30	10.9	11.3	11.9
3-10-77	5	0.96	0.96	1.03	0.50	0.57	0.60	11.6	10.9	12.1
3-16-77		0.88	0.89	1.00	0.38	0.45	0.46	10.0	9.8	11.5
3-17-77	21	0.96	0.90	1.05	0.47	0.54	0.40	9.8	10.2	11.4
3-24-77		1.02	0.92	0.99	0.38	0.52	0.56			
3-25-77	47	0.97	0.77	0.91	0.51	0.38	0.32			
3-30-77		0.97	0.93	1.05	0.37	0.42	0.42	9.4	10.0	10.7
3-31-77	36	0.74	0.77	0.92	0.39	0.47	0.57	8.8	10.4	10.4
4-6-77		1.14	0.96	1.02	0.42	0.52	0.52	9.9	10.4	10.4
4-7-77	22	1.20	1.08	1.05	0.47	0.48	0.46	9.9	10.1	11.1
4-13-77		0.77	0.83	1.10	0.36	0.36	0.52			
4-14-77	30	0.82	0.77	1.04	0.32	0.32	0.44			
4-19-77		1.04	0.94	1.07	0.33	0.34	0.44	8.8	7.2	9.4
4-20-77	43	0.91	0.88	1.01	0.34	0.32	0.46	9.0	7.8	9.4
4-28-77		1.01	0.89	1.04	0.25	0.29	0.36	9.8	8.0	8.1
4-29-77	34	0.96	0.87	1.01	0.17	0.13	0.24	8.8	8.8	9.9
5-4-77		0.93	0.83	1.11	0.16	0.21	0.26	8.4	8.0	9.3
5-5-77	40	0.79	0.77	1.07	0.23	0.21	0.30	8.5	7.9	8.8
5-12-77		0.79	0.78	1.00	0.25	0.23	0.34	8.1	7.7	9.5
5-13-77	67	0.85	0.80	1.06	0.27	0.23	0.35			
5-18-77		0.90	0.79	1.07	0.24	0.26	0.25			
5-19-77	43	0.92	0.87	1.03	0.29	0.34	0.37	8.2	6.8	8.4
5-26-77		0.86	0.68	0.87	0.21	0.22	0.29	7.8	6.6	8.2
5-27-77	64	1.02	0.83	1.09	0.08	0.13	0.28			
5-31-77		0.88	0.77	1.10	0.32	0.35	0.34	7.0	5.2	8.5
6-1-77	79	0.65	0.63	0.95	0.20	0.21	0.34	6.7	4.5	8.2
6-6-77		0.89	0.86	1.01	0.43	0.34	0.42			
6-7-77	14	0.72	0.39	0.74	0.14	0.25	0.18	7.6	6.4	8.0
6-13-77		0.80	0.78	0.91	0.20	0.12	0.18			
6-14-77	17	0.75	0.80	0.91	0.22	0.19	0.23	4.8	6.2	11.7
6-21-77		0.73	0.66	0.96	0.22	0.26	0.20			
6-22-77	52	0.60	0.55	1.00	0.14	0.14	0.22			
6-28-77		0.51	0.55	0.76	0.22	0.24	0.19			
6-29-77	83	0.74	0.42	0.70	0.17	0.19	0.40			
8-17-77		0.75	0.62	0.94	0.28	0.28	0.13	8.1	6.3	7.7
8-18-77	66	0.71	0.79	0.96	0.22	0.19	0.24			
8-25-77		1.00	0.82	1.04	0.24	0.21	0.31	8.0	7.0	8.0
8-26-77	122	0.83	0.85	0.94	0.16	0.12	0.30			
8-30-77		0.66	0.68	0.93	0.47	0.21	0.17	6.5	5.7	7.0
8-31-77	66	0.69	0.68	1.04	0.42	0.31	0.26			
9-6-77		0.68	0.78	0.97	0.35	0.40	0.51			
9-7-77	212	0.65	0.57	0.99	0.37	0.32	0.43			
9-13-77		0.60	0.63	0.97	0.43	0.34	0.33			
9-14-77	132	0.58	0.53	0.88	0.52	0.42	0.53			
9-21-77		0.79	0.81	0.90	0.14	0.14	0.17			
9-22-77	133	0.76	0.75	0.95	0.28	0.32	0.40			
9-28-77		0.86	0.88	1.14	0.18	0.18	0.20	8.2	7.5	9.1
9-29-77	40	0.88	0.89	0.97	0.07	0.12	0.18			
10-9-77		0.91	0.88	1.00	0.43	0.44	0.44			
10-10-77	53	0.76	0.77	1.04	0.31	0.22	0.32			
10-17-77		0.92	0.81	1.10	0.31	0.28	0.19			
10-18-77	5	1.03	0.80	1.05	0.39	0.32	0.42	9.1	7.7	10.0
10-23-77		0.73	0.71	0.92	0.35	0.31	0.39			
10-24-77	8	0.80	0.79	0.94	0.31	0.17	0.24			
10-31-77		1.04	1.08	1.12	0.22	0.18	0.43			
11-1-77	40	0.84	0.86	0.99	0.34	0.20	0.37	8.8	7.9	9.8
11-10-77		0.81	0.86	0.94	0.18	0.14	0.22	7.9	8.0	10.5
11-11-77	86	0.97	0.89	1.10	0.24	0.17	0.18			

(continued)

TABLE D-2. (continued).

Date	TTHM µg/l	Residual Chlorine, mg/l			Ammonia, mg/l			Dissolved Oxygen, mg/l		
		Settled Water								
		Secondary	Final	Delivered	River	Raw	Delivered	River	Raw	Delivered
11-22-77		1.12	1.09	1.23	0.23	0.20	0.22	10.2	10.6	11.6
11-23-77	28	1.22	1.14	1.17	0.39	0.56	0.24			
11-29-77		1.12	1.11	1.08	0.21	0.26	0.23	12.0	12.4	13.0
11-30-77	27	1.14	1.28	1.13	0.31	0.31	0.20			
12-14-77		1.07	1.08	1.04	0.73	0.65	0.49			
12-15-77	13	0.94	0.93	0.99	0.79	0.82	0.64	10.4	9.8	12.3
3-28-78		1.20	1.32	1.36	0.27	0.22	0.17	10.1	10.2	11.8
3-29-78	3	1.31	1.33	1.42	0.42	0.30	0.15			
4-7-78		1.20	1.28	1.30	0.50	0.50	0.34			
4-8-78	2	1.40	1.14	1.27	0.44	0.44	0.34			
4-13-78		0.80	0.81	1.07	0.34	0.28	0.13	8.2	6.5	10.2
4-14-78	1	0.95	0.90	1.11	0.25	0.23	0.26			
4-21-78		0.82	0.93	1.05	0.18	0.24	0.13			
4-22-78	1	0.70	0.83	1.01	0.26	0.22	0.22			
5-1-78		0.86	0.89	1.03	0.38	0.44	0.50			
5-2-78	4	0.87	0.98	1.02	0.69	0.51	0.67	9.4	9.8	11.0
5-14-78		0.77	0.78	0.89	0.27	0.24	0.22			
5-15-78	2	1.01	0.85	0.95	0.31	0.28	0.38			
5-21-78		0.75	0.79	0.93	0.55	0.60	0.42			
5-22-78	4	0.56	0.64	0.96	0.69	0.47	0.41			
6-1-78		--	--	0.96	0.43	0.46	0.40			
6-2-78	6	--	--	1.06	0.21	0.27	0.29			
7-18-78		0.88	0.82	0.98	0.45	0.53	0.36			
7-19-78	70	0.76	0.89	0.95	0.34	0.36	0.38			
7-23-78		0.55	0.60	0.97	0.41	0.37	0.40			
7-24-78	104	0.71	0.66	1.05	0.31	0.28	0.33			
7-30-78		0.88	0.72	0.91	0.19	0.20	0.17			
7-31-78	137	0.94	0.77	0.97	0.34	0.41	0.34	7.0	6.2	7.9
8-11-78		0.74	0.84	1.06	0.16	0.17	0.22			
8-12-78	38	0.83	0.89	1.15	0.36	0.14	0.19			
8-18-78		0.76	0.73	0.89	0.21	0.21	0.31			
8-19-78	37	0.63	0.74	1.03	0.34	0.23	0.17	7.1	6.6	7.8
8-26-78		1.00	0.92	1.05	0.24	0.16	0.26	8.0	7.0	8.5
8-27-78	34	0.85	0.93	1.06	0.23	0.33	0.47			
9-2-78		1.35	0.80	1.07	0.23	0.24	0.19			
9-3-78	24	1.32	1.00	1.05	0.31	0.29	0.46			
9-17-78		0.47	0.45	0.82	0.25	0.21	0.28			
9-18-78	7	0.88	0.37	0.77	0.48	0.24	0.60			
9-25-78		1.19	0.63	1.10	0.40	0.39	0.36			
9-26-78	46		1.14	1.11	0.37	0.35	0.38			
10-5-78		1.24	0.81	1.00	0.51	0.58	0.37			
10-6-78	35	1.02	0.90	0.84	0.48	0.39	0.37	9.4	8.7	9.9
10-12-78		1.27	1.07	0.90	0.50	0.55	0.66			
10-13-78	37	1.45	0.90	1.04	0.55	0.49	0.51			
10-21-78		1.32	0.97	1.03	0.37	0.37	0.47			
10-22-78	28	1.14	0.92	0.99	0.15	0.21	0.47			
10-28-78		1.46	1.03	1.09	0.48	0.43	0.66			
10-29-78	32	1.55	1.01	1.14	0.51	0.47	0.68			
11-11-78		1.50	0.96	1.00	0.42	0.37	0.64			
11-12-78	42	1.90	1.10	1.10	0.23	0.25	0.54			
11-24-78		1.71	1.00	1.17	0.54	0.60	0.67	11.7	10.7	13.8
11-25-78	49	1.56	0.99	1.00	0.31	0.31	0.39			

TABLE D-3. KANSAS CITY TREATMENT PLANT LABORATORY DATA--SUSPENDED AND DISSOLVED SOLIDS, SILICA AND FLUORIDE

Date	TTHM µg/l	Suspended Solids, mg/l		Dissolved Solids, mg/l		Silica, mg/l		Fluoride, mg/l	
		River	Final Settled Water	River	Raw	River	Delivered	River	Delivered
2-15-77		134	3	480	467	13.4	10.2	0.63	0.63
2-16-77	4	94	3	464	472	13.0	10.2	0.61	0.61
2-24-77		116	5	458	514	13.4	10.2	0.55	0.40
2-25-77	22	420	2	466	469	14.3	10.4	0.53	0.41
2-28-77		112	14	417	388	15.9	11.0	0.62	0.52
3-1-77	14	146	39	407	389	15.2	10.2	0.61	0.43
3-9-77		119	7	460	439	16.5	11.3	0.56	0.58
3-10-77	5	79	6	434	461	18.0	12.2	0.61	0.66
3-16-77		367	2	422	402	17.4	9.6	0.53	0.53
3-17-77	21	258	26	395	484	17.0	10.2	0.50	0.50
3-24-77		475	14	637	79	16.3	11.0	0.51	0.46
3-25-77	47	205	2	452	466	15.9	11.2	0.46	0.46
3-30-77		189	2	403	425	15.9	8.8	0.48	0.50
3-31-77	36	267	27	398	415	16.0	10.4	0.57	0.57
4-6-77		156	6	427	449	14.3	10.4	0.57	0.52
4-7-77	22	168	4	413	426	13.9	8.9	0.61	0.61
4-13-77		102	23	492	483	15.9	9.0	0.57	0.57
4-14-77	30	126	3	450	432	14.3	8.9	0.55	0.53
4-19-77		86	3	486	443	12.6	8.2	0.66	0.58
4-20-77	43	68	3	451	435	12.1	8.0	0.70	0.59
4-28-77		215	2	413	455	13.4	8.0	0.68	0.49
4-29-77	34	168	3	459	424	11.3	6.9	0.70	0.59
5-4-77		106	5	450	436	12.1	6.9	0.63	0.56
5-5-77	40	305	4	447	429	11.3	6.9	0.60	0.56
5-12-77		1285	26	398	428	11.3	6.9	0.57	0.49
5-13-77	67	768	14	500	453	12.6	8.0	0.58	0.51
5-18-77		280	6	439	434	12.6	8.0	0.67	0.53
5-19-77	43	218	3	464	488	11.5	7.4	0.58	0.47
5-26-77		1478	12	381	356	13.9	9.0	0.60	0.47
5-27-77	64	1390	43	423	437	13.9	8.9	0.63	0.57
5-31-77		1932	5	467	279	13.9	8.9	0.57	0.42
6-1-77	79	2848	2	287	339	12.1	9.1	0.62	0.62
6-6-77		372	3	293	371	16.3	11.0	0.60	0.62
6-7-77	14	338	5	407	401	14.3	9.1	0.67	0.58
6-13-77		197	3	510	363	12.6	9.6	0.62	0.62
6-14-77	17	135	4	451	428	12.1	8.2	0.57	0.54
6-21-77		137	5	405	390	11.7	6.9	0.63	0.55
6-22-77	52	603	2	411	442	11.7	6.9	0.63	0.49
6-28-77		1442	5	435	411	11.7	8.0	0.58	0.53
6-29-77	83	1655	3	376	368	13.0	8.9	0.59	0.55
8-17-77		1876	2	299	317	10.2	7.1	0.64	0.60
8-18-77	66	1004	6	654	471	10.0	6.5	0.59	0.55
8-25-77		361	2	366	301	10.7	6.5	0.52	0.60
8-26-77	122	633	1	451	465	11.3	6.0	0.70	0.57
8-30-77		1776	4	310	378	10.7	6.0	0.50	0.58
8-31-77	66	889	4	284	329	10.4	7.3	0.52	0.58
9-6-77		1871	2	205	233	12.5	8.5	0.58	0.53
9-7-77	212	1798	10	238	229	11.9	9.7	0.51	0.60
9-13-77		3779	5	243	229	10.7	9.7	0.45	0.49
9-14-77	132	2933	8	218	195	11.3	7.2	0.42	0.44
9-21-77		821	4	396	500	13.4	9.6	0.58	0.47
9-22-77	133	478	2	382	244	13.4	8.9	0.66	0.53
9-28-77		728	60	290		13.4	9.0	0.67	0.69
9-29-77	40	19	11	543	382	13.4	8.5	0.64	0.63
10-9-77		882	32	393	444				
10-10-77	53	1337	7	387	231	13.7	9.3	0.57	0.60
10-17-77		58	3	421	407	15.5	9.2	0.67	0.56
10-18-77	5	171	71	473	451	14.8	8.9	0.75	0.55
10-23-77		2554	10	381	378				
10-24-77	8	229	9	1001	1440	14.2	9.3	0.56	0.50
10-31-77		196	1	332	288	14.1	9.5	0.54	0.47
11-1-77	40	1075	14	388	369	13.9	9.6	0.54	0.53
11-10-77		1681	10	328	379	13.9	9.6	0.52	0.50

(continued)

TABLE D-3. (continued).

Date	TTHM µg/l	Suspended Solids, mg/l		Dissolved Solids, mg/l		Silica, mg/l		Fluoride, mg/l	
		River	Final Settled Water	River	Raw	River	Delivered	River	Delivered
11-11-77	86	1205	41	306	413				
11-22-77		100	7	445	501	16.5	10.2	0.64	0.52
11-23-77	28	29	19	485	411	16.5	10.6	0.68	0.64
11-29-77		15	5	502	345	15.4	10.6	0.60	0.54
11-30-77	27	14	3	425	430	16.8	11.4	0.73	0.51
12-14-77		377	12	384	423	15.1	11.8	0.59	0.53
12-15-77	13	71	4	485	575	18.2	10.4	0.68	0.47
3-28-78		924	7	248	237	11.3	8.4	0.41	0.54
3-29-78	3	692	4	275	278	12.9	9.5	0.41	0.41
4-7-78		1311	6	261	246	17.1	12.2	0.46	0.50
4-8-78	2	323	11	266	277				
4-13-78		2833	7	275	277	13.6	10.3	0.44	0.51
4-14-78	1	1435	6	306	378	14.3	10.0	0.46	0.50
4-21-78		787	4	298	291	16.4	12.6	0.36	0.33
4-22-78	1	1148	11	262	290				
5-1-78		468	14	408	410	15.5	10.8	0.55	0.63
5-2-78	4	402	5	438	443	15.6	11.0	0.49	0.49
5-14-78		1334	6	320	361				
5-15-78	2	1067	3	362	375	12.5	9.3	0.41	0.50
5-21-78		1627	19	450	448				
5-22-78	4	2034	26	387	410	10.9	8.1	0.26	0.29
6-1-78		2080	2	399	402	11.2	7.5	0.34	0.41
6-2-78	6	6334	3	411	385	12.2	7.6	0.44	0.44
7-18-78		566	3	415	376	12.0	5.6	0.42	0.28
7-19-78	70	247	7	434	415	11.5	6.5	0.42	0.24
7-23-78		3175	6	393	435				
7-24-78	104	4624	4	245	248	10.0	6.9	0.42	0.28
7-30-78		191	5	393	409				
7-31-78	137	323	6	412	386	10.2	6.9	0.51	0.25
8-11-78		114	2	482	477	8.5	5.6	0.41	0.25
8-12-78	38	17	5	480	463				
8-18-78		200	3	472	433	9.5	6.5	0.41	0.25
8-19-78	37	144	5	466	479				
8-26-78		135	5	490	426				
8-27-78	34	254	87	455	451				
9-2-78		247	5	343	492				
9-3-78	24	110	35	493	518				
9-17-78		1920	25	340	337				
9-18-78	7	1650	6	435	433	10.0	6.3	0.40	0.24
9-25-78		1146	10	475	413	10.8	5.2	0.42	0.25
9-27-78	46	419	14	494	486	10.0	5.5	0.44	0.23
10-5-78		122	24	461	508	12.5	7.8	0.35	0.39
10-6-78	35	89	18	422	408	11.7	8.3	0.32	0.41
10-12-78		42	6	539	427	10.6	6.9	0.45	0.30
10-13-78	37	105	3	535	525	10.6	6.9	0.50	0.30
10-21-78		139	26	493	469	6.2	4.1	0.41	0.27
10-22-78	28	3	2	511	401	10.0	7.2	0.50	0.33
10-28-78		78	26	458	445	10.8	7.4	0.52	0.34
10-29-78	32	44	45	409	381	10.3	7.5	0.43	0.29
11-11-78		107	28	500	505	10.8	7.4	0.43	0.28
11-12-78	42	39	45	428	438	10.5	7.2	0.46	0.29
11-24-78		108	4	455	465	10.4	7.8	0.42	0.28
11-25-78	49	82	33	464	441	10.1	8.3	0.39	0.28

TABLE D-4. KANSAS CITY TREATMENT PLANT LABORATORY DATA--pH AND PHENOLPHTHALEIN ALKALINITY

Date	TTHM µg/l	pH						Phenolphthalein Alkalinity, mg/l $CaCO_3$**		
				Settled Water				Settled Water		
		River	Raw	Secondary	Final	Delivered	LCSI*	Secondary	Final	Delivered
2-15-77		8.1	8.1	11.6	10.2	10.0	1.8	130	43	36
2-16-77	4	8.1	7.9	11.6	9.8	9.9	1.7	117	36	32
2-24-77		8.1	8.0	11.5	9.8	9.9	1.6	116	29	28
2-25-77	22	8.2	8.0	11.4	10.0	9.9	1.6	99	33	30
2-28-77		8.2	8.2	11.5	10.0	9.9	1.6	109	30	28
3-1-77	14	8.1	8.1	11.5	10.0	9.9	1.6	112	32	30
3-9-77		7.9	8.1	11.3	10.0	10.1	1.8	91	29	35
3-10-77	5	8.2	8.2	11.4	10.4	10.2	1.9	107	42	37
3-16-77		8.0	8.0	11.3	9.9	9.9	1.6	92	23	25
3-17-77	21	8.1	8.1	11.3	9.8	9.9	1.7	113	24	27
3-24-77		8.0	7.9	11.3	10.0	10.0	1.7	99	33	27
3-25-77	47	8.1	7.9	10.6	9.6	10.1	1.9	110	25	31
3-30-77		8.1	8.0	11.3	10.0	9.8	1.5	92	24	23
3-31-77	36	8.0	8.0	11.2	9.9	10.0	1.8	85	31	36
4-6-77		8.0	8.0	11.4	10.1	10.0	1.6	86	24	25
4-7-77	22	8.2	8.1	11.4	9.9	10.0	1.7	103	21	22
4-13-77		8.2	8.1	11.4	9.4	9.9	1.6	111	17	24
4-14-77	30	8.2	8.2	11.3	10.0	10.1	1.9	99	31	35
4-19-77		8.2	8.1	11.2	10.1	9.9	1.7	70	26	26
4-20-77	43	8.2	8.1	11.2	9.9	10.1	1.9	92	19	25
4-28-77		8.2	8.0	11.1	9.9	10.0	1.8	84	24	26
4-29-77	34	8.3	8.1	11.1	9.7	10.0	1.8	83	24	25
5-4-77		8.2	8.0	11.0	10.0	10.0	1.8	94	27	29
5-5-77	40	8.3	8.1	11.0	10.0	10.1	1.9	92	22	25
5-12-77		8.0	7.9	11.0	9.9	10.0	1.8	72	23	24
5-13-77	67	8.1	8.0	10.9	9.9	10.0	1.8	83	21	24
5-18-77		8.3	8.1	10.9	10.0	10.1	2.0	95	27	27
5-19-77	43	8.2	8.1	10.9	9.9	10.0	1.9	93	21	29
5-26-77		8.0	7.9	11.2	9.9	9.8	1.7	110	24	24
5-27-77	64	8.1	7.9	11.1	9.7	9.8	1.7	92	21	21
5-31-77		8.0	7.9	11.1	9.8	9.9	1.8	101	25	22
6-1-77	79	8.1	8.0	11.2	9.7	9.7	1.6	102	22	22
6-6-77		8.1	7.9	11.0	10.1	10.3	2.3	79	33	38
6-7-77	14	8.2	8.1	11.2	10.2	10.4	2.4	106	33	41
6-13-77		8.2	8.1	11.1	10.1	10.0	1.9	86	28	28
6-14-77	17	8.3	8.1	11.2	10.1	10.1	2.0	110	29	30
6-21-77		8.3	8.2	11.1	10.0	10.0	1.9	83	24	23
6-22-77	52	8.1	7.9	11.1	10.0	10.1	1.9	86	21	24
6-28-77		8.0	7.8	11.0	9.7	9.9	1.8	87	20	22
6-29-77	83	7.9	7.8	11.0	9.9	9.9	1.9	82	23	26
8-17-77		8.1	8.1	11.0	9.8	9.8	1.8	88	24	22
8-18-77	66	7.9	7.9	11.0	9.7	9.8	1.8	87	19	23
8-25-77		8.0	8.0	11.0	10.0	10.0	2.0	86	26	27
8-26-77	122	8.0	8.2	10.9	9.9	10.0	1.9	84	25	27
8-30-77		7.8	7.8	11.0	10.1	10.0	2.0	99	36	36
8-31-77	66	7.9	7.8	11.0	10.0	10.0	1.9	95	29	27
9-6-77		7.7	7.6	10.9	9.6	9.4	1.3	70	20	18
9-7-77	212	7.7	7.6	11.0	10.0	10.0	1.8	79	27	25
9-13-77		7.9	7.9	11.0	9.9	10.0	1.8	78	22	23
9-14-77	132	8.0	7.8	11.0	9.9	9.9	1.8	85	27	26
9-21-77		8.0	8.0	11.0	9.9	9.8	1.7	78	29	25
9-22-77	133	8.1	8.1	11.0	10.0	10.0	1.8	81	28	28
9-28-77		8.0	8.0	11.1	9.9	9.8	1.6	86	25	23
9-29-77	40	8.1	8.1	11.0	9.8	9.8	1.6	81	22	23
10-9-77		8.1	8.1	11.2	9.8	9.8	1.4	96	19	18
10-10-77	53	8.1	8.0	11.2	9.9	9.8	1.5	104	25	22
10-17-77		8.2	8.0	11.2	10.0	10.0	1.8	93	28	30
10-18-77	5	8.2	8.1	11.3	10.0	10.0	1.7	96	23	25
10-23-77		8.2	8.2	11.2	9.8	10.0	1.6	124	24	24
10-24-77	8	8.1	8.2	11.4	10.0	10.1	1.9	123	30	30
10-31-77		8.4	8.4	11.1	10.0	9.7	1.4	84	26	26
11-1-77	40	8.0	8.1	10.9	9.9	10.0	1.5	114	30	29
11-10-77		7.9	7.8	11.6	10.1	10.1	1.8	107	35	29

(continued)

TABLE D-4. (continued).

Date	TTHM µg/l	pH					LCSI*	Phenolphthalein Alkalinity, mg/l $CaCO_3$**		
		River	Raw	Settled Water Secondary	Settled Water Final	Delivered		Settled Water Secondary	Settled Water Final	Delivered
11-11-77	86	8.0	7.9	11.5	10.0	9.8	1.7	96	32	33
11-22-77		8.2	8.2	11.7	10.1	10.1	1.8	91	25	29
11-23-77	28	8.2	8.2	11.6	10.3	10.0	1.6	92	28	25
11-29-77		8.2	8.2	11.9	10.3	10.1	1.8	109	39	38
11-30-77	27	8.1	8.2	11.9	10.4	10.3	2.1	104	37	36
12-14-77		8.0	7.9	11.7	10.4	10.3	2.0	155	43	42
12-15-77	13	7.9	7.7	11.6	10.4	10.2	1.9	145	43	39
3-28-78		7.8	7.9	11.4	10.0	10.1	1.6	110	24	23
3-29-78	3	7.8	7.8	11.6	9.9	10.0	1.5	111	25	22
4-7-78		7.8	7.8	11.4	9.8	9.8	1.7	119	30	31
4-8-78	2	7.9	7.7	11.4	10.0	10.0	1.8	123	32	35
4-13-78		7.7	7.8	11.4	10.2	10.2	1.9	108	32	31
4-14-78	1	7.8	7.8	11.4	10.1	10.2	2.0	119	30	32
4-21-78		7.9	7.9	11.4	9.9	9.8	1.6	103	24	23
4-22-78	1	7.8	7.8	11.4	10.0	9.9	1.6	100	30	26
5-1-78		8.1	8.0	11.6	9.8	9.9	1.7	106	23	25
5-2-78	4	8.1	8.2	11.5	9.9	10.0	1.8	103	24	27
5-14-78		8.1	8.1	11.1	10.0	9.8	1.6	92	25	24
5-15-78	2	8.2	8.1	11.1	10.2	10.0	1.8	84	32	28
5-21-78		8.1	8.1	10.9	9.9	9.9	1.7	74	21	21
5-22-78	4	8.2	8.0	11.1	9.8	9.9	1.6	85	20	19
6-1-78		8.2	8.1	11.1	9.9	10.0	2.0	102	23	28
6-2-78	6	8.1	8.2	11.2	9.6	9.7	1.7	103	16	20
7-18-78		8.0	8.1	11.1	9.6	10.0	2.0	98	20	24
7-19-78	70	8.1	8.0	11.1	9.7	9.8	1.8	93	17	16
7-23-78		7.9	7.9	11.0	9.9	9.9	1.9	97	25	24
7-24-78	104	8.0	7.8	11.1	10.0	10.0	2.0	103	35	35
7-30-78		8.1	8.1	10.9	10.0	9.9	1.8	66	27	25
7-31-78	137	8.1	8.1	11.0	9.9	10.0	2.0	72	26	28
8-11-78		8.3	8.3	10.6	9.9	9.8	1.5	70	25	23
8-21-78	38	8.4	8.3	10.8	9.8	9.9	1.7	76	21	25
8-18-78		8.3	8.5	10.5	9.8	9.7	1.7	77	24	25
8-19-78	37	8.3	8.3	10.9	9.7	9.9	2.0	92	24	27
8-26-78		8.4	8.5	10.6	9.6	9.8	1.8	72	20	24
8-27-78	34	8.5	8.5	10.7	9.9	9.8	1.7	71	24	24
9-2-78		8.4	8.4	10.6	9.8	10.0	1.9	69	27	28
9-3-78	24	8.5	8.5	10.6	9.9	9.9	1.9	67	25	25
9-17-78		8.2	8.2	10.5	9.7	9.9	2.0	84	24	27
9-18-78	7	8.2	8.2	10.5	9.8	9.9	1.8	78	25	29
9-25-79		8.3	8.3	10.8	9.8	9.9	1.9	79	27	28
9-26-78	46	8.3	8.2	10.6	9.9	10.0	1.9	67	27	28
10-5-78		8.4	8.4	10.7	9.9	9.9	1.6	79	20	18
10-6-78	35	8.5	8.5	10.8	9.8	9.8	1.6	86	23	23
10-12-78		8.6	8.6	10.8	9.8	9.8	1.6	83	25	22
10-13-78	37	8.6	8.6	10.8	9.7	9.8	1.5	87	27	24
10-21-78		8.6	8.6	10.6	10.1	10.0	1.8	94	32	27
10-22-78	28	8.4	8.5	10.3	9.8	10.0	2.0	88	29	28
10-28-78		8.3	8.3	11.5	9.9	9.9	1.8	95	27	27
10-29-78	32	8.3	8.4	11.5	10.1	10.1	2.0	103	31	35
11-11-78		8.3	8.3	11.5	9.8	9.9	1.7	89	24	27
11-12-78	42	8.4	8.4	11.6	9.8	10.0	1.8	89	24	28
11-24-78		8.2	8.2	11.4	10.0	10.0	1.7	102	28	26
11-25-78	49	8.2	8.2	11.4	10.0	10.0	1.6	102	23	24

*Langlier's calcium carbonate saturation index.

**Phenolphthalein alkalinity of river and raw water was 0 except on the following days: 1 mg/l on 8-11-78, 8-12-78, 8-19-78, and 10-6-78 in both river and raw, and 10-5-78 in the river alone; 2 mg/l on 9-2-78 in both river and raw, 4-29-77 in the river alone, and 10-24-77, 9-3-78, and 10-13-78 in the raw alone: and 3 mg/l on 8-27-78 (river and raw), 9-3-78 (river), and 10-13-78 (river).

TABLE D-5. KANSAS CITY TREATMENT PLANT LABORATORY DATA--METHYL ORANGE ALKALINITY AND TOTAL HARDNESS

Date	TTHM µg/l	Methyl Orange Alkalinity, mg/l $CaCO_3$					Total Hardness, mg/l $CaCO_3$		
		River	Raw	Settled Water Secondary	Settled Water Final	Delivered	River	Raw	Delivered
2-15-77		169	171	148	84	73	241	242	144
2-16-77	4	167	169	139	85	72	244	245	145
2-24-77		157	162	132	64	65	217	220	125
2-25-77	22	163	166	119	72	70	212	217	132
2-28-77		154	155	125	66	66	209	209	125
3-1-77	14	155	155	128	65	64	210	208	120
3-9-77		167	168	108	65	65	225	225	123
3-10-77	5	166	168	123	73	68	223	220	120
3-16-77		162	161	105	52	56	217	218	110
3-17-77	21	160	162	125	54	59	215	213	113
3-24-77		154	158	118	60	54	218	221	119
3-25-77	47	149	154	126	62	67	214	211	133
3-30-77		145	148	105	51	53	205	209	114
3-3-1-77	36	153	153	106	70	72	211	211	135
4-6-77		161	161	101	48	48	226	225	113
4-7-77	22	159	160	118	47	50	222	223	115
4-13-77		160	160	124	51	55	231	233	119
4-14-77	30	162	162	113	63	64	233	233	134
4-19-77		158	160	87	55	57	227	228	126
4-20-77	43	155	158	105	43	48	224	226	117
4-28-77		159	158	95	51	54	224	226	120
4-29-77	34	158	161	95	52	52	227	226	117
5-4-77		157	159	106	54	56	226	226	121
5-5-77	40	157	160	104	45	47	227	228	112
5-12-77		149	151	85	53	51	216	216	117
5-13-77	67	152	154	96	46	50	211	214	115
5-18-77		154	155	106	54	54	221	223	117
5-19-77	43	153	153	105	49	52	222	222	118
5-26-77		138	142	122	53	54	196	199	110
5-27-77	64	139	144	105	55	53	184	190	110
5-31-77		138	140	112	54	51	211	207	113
6-1-77	79	134	137	115	54	54	187	194	111
6-6-77		139	144	93	60	65	208	207	121
6-7-77	14	147	148	119	60	67	210	210	124
6-13-77		151	149	98	49	50	223	215	117
6-14-77	17	152	151	122	56	55	215	216	121
6-21-77		148	148	94	46	48	211	213	111
6-22-77	52	139	140	97	42	47	197	200	107
6-28-77		140	140	112	47	52	197	196	111
6-29-77	83	128	130	92	46	55	185	186	113
8-17-77		128	128	99	54	53	190	190	117
8-18-77	66	120	121	97	53	54	182	181	121
8-25-77		143	143	95	54	54	214	211	119
8-26-77	122	145	145	93	52	55	217	213	121
8-30-77		109	110	110	69	69	165	162	137
8-31-77	66	117	119	106	59	53	176	174	112
9-6-77		100	100	83	56	54	133	131	100
9-7-77	212	102	103	93	55	45	135	137	96
9-13-77		96	99	91	46	44	136	131	97
9-14-77	132	98	98	99	55	54	132	128	101
9-21-77		142	143	91	54	56	199	198	108
9-22-77	133	150	149	93	52	52	215	214	111
9-28-77		148	148	98	51	48	205	205	105
9-29-77	40	152	152	92	53	52	214	213	114
10-9-77		144	143	108	45	43	202	206	107
10-10-77	53	138	138	116	55	51	188	187	104
10-17-77		164	162	104	56	59	229	226	117
10-18-77	5	167	164	107	46	50	234	229	115
10-23-77		130	130	137	54	47	179	181	105
10-24-77	8	129	129	136	62	62	170	169	107
10-31-77		157	158	96	56	56	220	217	109
11-1-77	40	135	133	125	53	48	184	183	101
11-10-77		118	118	122	62	53	163	160	115
11-11-77	86	120	121	113	70	70	173	166	131

(continued)

TABLE D-5. (continued).

Date	TTHM µg/l	Methyl Orange Alkalinity, mg/l $CaCO_3$					Total Hardness, mg/l $CaCO_3$		
				Settled Water					
		River	Raw	Secondary	Final	Delivered	River	Raw	Delivered
11-22-77		177	177	105	52	53	260	260	129
11-23-77	28	176	180	107	56	51	249	247	126
11-29-77		183	184	125	75	74	263	261	149
11-30-77	27	189	189	122	72	74	262	261	150
12-14-77		247	236	175	75	74	324	304	143
12-15-77	13	226	218	160	69	66	310	293	137
3-28-78		125	121	131	51	44	154	155	91
3-29-78	3	128	121	129	55	49	166	164	94
4-7-78		131	132	136	74	77	170	168	115
4-8-78	2	129	131	140	65	69	169	171	109
4-13-78		129	128	129	57	55	174	174	112
4-14-78	1	138	137	131	57	59	187	185	109
4-21-78		122	122	119	57	57	163	154	104
4-22-78	1	130	130	115	51	57	172	174	103
5-1-78		175	176	120	56	57	250	246	117
5-2-78	4	181	180	117	56	55	244	254	118
5-14-78		151	152	105	50	50	209	206	105
5-15-78	2	168	166	98	55	51	232	229	107
5-21-78		169	169	85	49	46	243	239	112
5-22-78	4	158	157	95	50	46	227	244	110
6-1-78		144	145	113	49	59	209	207	119
6-2-78	6	142	140	115	47	53	201	205	110
7-18-78		141	142	109	49	51	217	214	126
7-19-78	70	142	143	102	43	42	219	217	120
7-23-78		112	116	109	52	53	165	171	125
7-24-78	104	103	103	115	67	66	148	145	119
7-30-78		150	149	78	56	54	220	228	125
7-31-78	137	151	152	83	54	55	231	235	129
8-11-78		157	158	83	46	45	241	239	121
8-12-78	38	158	158	85	47	48	239	240	135
8-18-78		156	155	89	51	53	231	234	127
8-19-78	37	156	156	101	55	58	234	233	131
8-26-78		154	154	81	50	54	231	231	131
8-27-78	34	156	157	81	49	50	238	235	127
9-2-78		163	162	79	53	55	235	238	129
9-3-78	24	164	164	78	50	51	243	245	129
9-17-78		127	127	95	57	59	194	193	123
9-18-78	7	126	127	89	53	58	193	193	125
9-25-78		151	150	91	58	58	224	227	125
9-26-78	46	156	159	82	57	55	239	237	133
10-5-78		157	156	90	43	38	243	245	125
10-6-78	35	159	160	97	51	50	247	247	129
10-12-78		159	160	98	57	51	245	245	126
10-13-78	37	159	159	97	54	48	246	246	129
10-21-78		156	156	106	59	50	237	237	123
10-22-78	28	156	156	99	67	57	235	238	141
10-28-78		156	154	107	57	58	238	238	129
10-29-78	32	156	154	116	60	65	233	231	144
11-11-78		156	156	101	56	56	231	231	127
11-12-78	42	157	148	104	54	56	235	232	134
11-24-78		154	154	118	55	51	234	238	126
11-25-78	49	154	153	118	47	47	231	234	131

TABLE D-6. KANSAS CITY TREATMENT PLANT LABORATORY DATA--CALCIUM, MAGNESIUM, CHLORIDE AND SULFATE

Date	TTHM µg/l	Calcium, mg/l		Magnesium, mg/l		Chloride, mg/l		Sulfate, mg/l	
		River	Delivered	River	Delivered	River	Delivered	River	Delivered
2-15-77		64.4	51.9	19.5	3.5	28.8	31.2	238	221
2-16-77	4	64.3	50.9	20.3	4.4	26.8	29.2	264	275
2-24-77		52.2	42.0	21.1	4.9	24.8	27.3		
2-25-77	22	53.5	39.5	19.1	8.1	25.5	27.8		
2-28-77		54.7	42.5	17.6	4.6	25.5	28.2		
3-1-77	14	49.7	40.8	20.9	4.4	23.5	28.3	117	150
3-9-77		56.7	37.6	20.3	7.1	27.5	30.8	213	211
3-10-77	5	55.9	40.6	20.3	4.5	27.2	30.0	190	201
3-16-77		56.1	37.9	18.7	3.7	27.0	28.8	242	183
3-17-77	21	55.3	39.8	18.7	3.3	26.7	29.2	227	181
3-24-77		56.9	35.0	18.5	7.7	25.5	30.0		
3-25-77	47	55.3	36.8	18.5	10.0	25.8	28.5		
3-30-77		54.0	38.9	17.1	4.1	25.7	28.3	190	187
3-31-77	36	57.5	45.6	16.4	5.1	25.0	27.3	219	197
4-6-77		57.9	37.3	19.8	4.8	24.8	27.2	226	201
4-7-77	22	57.8	39.3	18.9	4.1	24.7	27.3	221	275
4-13-77		59.9	42.5	19.8	3.1	24.5	27.5		
4-14-77	30	60.6	46.7	19.9	4.2	25.2	28.2		
4-19-77		57.5	39.6	20.3	6.6	23.8	27.8	144	118
4-20-77	43	57.8	40.7	19.4	3.7	23.7	27.3	135	121
4-28-77		57.6	42.4	19.5	3.4	22.5	25.0	144	144
4-29-77	34	56.2	39.8	21.1	4.3	22.5	25.3	129	132
5-4-77		57.4	43.5	20.1	3.0	22.8	25.8	156	155
5-5-77	40	58.7	40.2	19.6	2.8	22.3	25.7	168	149
5-12-77		55.1	39.7	19.1	4.3	24.2	26.5	208	174
5-13-77	67	53.2	36.2	19.0	6.0	23.7	27.5		
5-18-77		56.4	41.9	19.5	3.0	23.8	26.3		
5-19-77	43	58.6	41.5	18.4	3.5	23.8	26.8	160	202
5-26-77		50.0	38.6	17.3	3.3	23.7	27.2	147	172
5-27-77	64	44.2	36.3	17.9	4.7	21.3	25.8		
5-31-77		56.7	39.5	16.9	3.5	25.7	28.3	132	134
6-1-77	79	49.1	38.7	15.7	3.5	24.2	27.3	231	213
6-6-77		55.6	38.9	16.8	5.8	23.2	25.5		
6-7-77	14	57.3	41.6	16.3	4.9	22.8	25.8	126	121
6-13-77		57.9	35.6	19.1	6.8	24.2	26.0		
6-14-77	17	57.0	42.7	17.7	3.5	24.2	26.7	160	141
6-21-77		53.1	39.2	19.1	3.2	23.3	24.8		
6-22-77	52	51.4	37.9	16.7	3.0	21.2	24.8		
6-28-77		49.6	38.4	17.9	3.7	23.3	26.3		
6-29-77	83	48.9	39.3	15.3	3.6	22.8	27.0		
8-17-77		49.6	41.9	16.1	3.0	22.2	25.3	176	200
8-18-77	66	47.4	43.3	15.5	3.1	23.5	26.7		
8-25-77		53.9	42.2	19.3	3.3	22.5	24.3	223	177
8-26-77	122	57.4	43.0	17.9	3.3	21.3	27.7		
8-30-77		47.5	50.4	11.3	2.7	23.2	26.8	92	172
8-31-77	66	47.9	41.4	13.7	2.1	25.3	28.8		
9-6-77		37.3	32.5	9.7	4.6	18.8	20.7		
9-7-77	212	35.5	31.5	11.3	4.2	23.8	27.0		
9-13-77		35.2	31.4	11.7	4.5	20.3	24.0		
9-14-77	132	34.3	34.8	11.3	3.4	20.7	24.5		
9-21-77		52.4	35.8	16.6	4.5	19.3	21.8		
9-22-77	133	56.2	36.7	18.2	4.7	19.2	22.3		
9-28-77		49.4	34.8	19.9	4.4	19.3	23.7	131	131
9-29-77	40	55.1	39.5	18.6	3.7	19.2	24.3		
10-9-77		51.9	35.7	17.6	4.3	19.3	22.7		
10-10-77	53	50.9	37.2	14.8	2.7	20.7	24.5		
10-17-77		59.0	39.6	19.9	4.4	20.5	22.5		
10-18-77	5	61.9	39.9	19.3	3.7	23.3	25.0	96	123
10-23-77		46.3	37.4	15.4	2.8	22.7	23.2		
10-24-77	8	46.2	39.0	13.3	2.3	18.5	23.5		
10-31-77		58.0	35.4	18.3	5.0	20.0	21.3		
11-1-77	40	47.5	31.5	15.9	5.4	17.3	21.3	148	161
11-10-77		43.1	38.0	13.5	4.9	16.8	19.0	107	175
11-11-77	86	49.4	46.7	12.1	3.5	18.8	21.5		
11-22-77		70.7	44.9	20.3	4.1	19.0	21.3	165	231

(continued)

TABLE D-6. (continued).

Date	TTHM µg/l	Calcium, mg/l		Magnesium, mg/l		Chloride, mg/l		Sulfate, mg/l	
		River	Delivered	River	Delivered	River	Delivered	River	Delivered
11-23-77	28	66.3	41.4	20.3	5.5	21.2	22.2		
11-29-77		69.4	50.1	21.8	5.8	19.5	21.0	125	137
11-30-77	27	68.7	50.0	22.0	6.1	21.8	23.2		
12-14-77		85.8	51.1	26.7	3.7	31.7	25.5		
12-15-77	13	82.3	47.6	25.4	4.4	32.0	28.0	205	178
3-28-78		43.6	29.7	11.0	4.1	17.3	19.3	101	148
3-29-78	3	40.3	30.2	14.9	4.5	15.2	17.2		
4-7-78		47.2	40.3	12.7	3.5	22.0	23.3		
4-8-78	2	54.3	38.3	8.1	2.9	22.5	22.3		
4-13-78		50.7	38.6	11.5	3.8	23.1	28.2	89	82
4-14-78	1	54.1	36.1	12.6	4.6	19.3	23.7		
4-21-78		44.7	36.2	12.5	3.3	19.5	20.2		
4-22-78	1	47.2	35.6	13.2	3.4	19.2	20.2		
5-1-78		67.4	40.7	19.9	3.7	22.7	24.3		
5-2-78	4	66.3	39.8	19.1	4.5	26.0	24.5	181	158
5-14-78		55.7	35.4	17.0	4.0	17.3	19.5		
5-15-78	2	62.3	35.6	18.6	4.4	20.0	21.8		
5-21-78		62.9	36.9	20.9	4.8	21.0	23.2		
5-22-78	4	58.8	36.0	19.5	4.9	23.8	26.0		
6-1-78		59.2	42.7	14.9	3.0	23.0	26.0		
6-2-78	6	54.5	39.1	15.8	3.0	17.3	20.5		
7-18-78		53.7	45.0	20.7	3.3	21.3	20.7		
7-19-78	70	55.5	41.6	19.6	3.9	21.3	22.3		
7-23-78		44.0	43.1	13.4	4.2	20.0	22.2		
7-24-78	104	38.4	42.0	12.7	3.4	22.2	25.2		
7-30-78		56.3	39.2	19.3	6.6	18.8	21.2		
7-31-78	137	59.1	44.1	20.3	4.6	20.7	25.2	161	160
8-11-78		58.7	40.0	23.0	5.1	20.2	22.7		
8-12-78	38	54.8	46.6	24.9	4.5	20.2	24.2		
8-18-78		56.2	44.9	22.1	3.6	21.3	25.7		
8-19-78	37	59.0	49.6	21.1	1.7	18.7	22.5	244	209
8-26-78		61.1	45.5	19.1	4.2	19.8	24.3	200	188
8-27-78	34	59.8	43.1	21.6	4.7	20.8	25.0		
9-2-78		60.5	44.9	20.4	4.1	20.2	23.7		
9-3-78	24	63.9	44.9	20.3	4.1	20.7	23.2		
9-17-78		51.4	43.8	16.0	3.3	19.3	22.8		
9-18-78	7	52.9	44.3	14.8	3.5	20.2	22.5		
9-25-78		60.6	42.3	17.7	4.7	19.7	23.0		
9-26-78	46	63.5	44.2	19.6	5.5	19.3	22.7		
10-5-78		65.2	42.3	19.5	4.7	20.2	23.7		
10-6-78	35	66.0	43.7	20.0	4.8	21.8	24.8	236	183
10-12-78		63.7	43.2	20.9	4.4	22.0	24.8		
10-13-78	37	64.0	45.4	21.0	3.8	22.0	24.8		
10-21-78		62.7	44.0	19.6	3.2	17.3	20.0		
10-22-78	28	61.2	52.0	20.0	2.7	17.8	20.8		
10-28-78		63.2	46.5	19.5	3.1	13.8	17.3		
10-29-78	32	61.7	51.0	19.2	4.0	16.7	19.3		
11-11-78		60.3	44.9	19.6	3.6	17.3	19.3		
11-12-78	42	59.1	47.2	21.3	3.9	17.3	18.5		
11-24-78		60.8	43.0	20.0	4.5	19.2	21.8	193	186
11-25-78	49	60.7	45.0	19.3	4.5	15.0	15.5		

TABLE D-7. KANSAS CITY TREATMENT PLANT DATA--CHLORINE, AMMONIA, POTASSIUM PERMANGANATE, CARBON, INORGANIC COAGULANT, AND POLYMER

Date	TTHM (µg/l)	Chlorine (lb/MG)	Ammonia (lb/MG)	Potassium Permanganate (lb/MG)	Carbon (lb/MG)	Inorganic Coagulant (lb/MG)	Polymer (lb/MG)
2-15-77		17	3.7	2			
2-16-77	4	20	1.6	3	1		
2-24-77		29	7.1	4	12		0.4N
2-25-77	22	31	7.7	4	8		0.3N
2-28-77		25	4.6	5			
3-1-77	14	27	6.6	6	17		
3-9-77		29	5.5	6	6	63A	
3-10-77	5	24	7.2	8	3		
3-16-77		32	6.6	6	16		
3-17-77	21	30	8.1	5	16		
3-24-77		42	5.7	2			5.3N
3-25-77	47	39	5.4	3			3.3N
3-30-77		33	7.9	5	14	23A	1.0N
3-31-77	36	29	6.8	3	5	29A	
4-6-77		23	7.1	1			
4-7-77	22	31	6.8	3			
4-13-77		31	6.5	5			
4-14-77	30	33	8.1	5			
4-19-77		31	7.7	5			
4-20-77	43	30	7.4	5		3F	
4-28-77		35	9.1	4	8		
4-29-77	34	33	8.3	3	7		
5-4-77		25	7.4	6			
5-5-77	40	26	7.9	6			1.1N
5-12-77		38	7.9	14	9	[redacted]	1.4D
5-13-77	67	45	9.1	8	3		2.0D
5-18-77		34	7.4	3			
5-19-77	43	32	8.1	4			0.8D
5-26-77		64	7.9	8	9	110A	4.0D
5-27-77	64	62	7.9	9	2	159A	5.2D
5-31-77		81	8.8	9		62A	3.5D
6-1-77	79	75	10.2	12	9	46A, 10F	1.6D
6-6-77		28	6.6	9			0.7D
6-7-77	14	12	6.7	10			0.5D
6-13-77		32	6.1	7			
6-14-77	17	31	3.8	6			
6-21-77		36	9.3	7	8		0.9D
6-22-77	52	61	2.6	9	9		4.0D
6-28-77		66	6.4	13			6.5N
6-29-77	83	82	7.1	12		127A, 16F	18.1N
8-17-77		64	10.9	32	12		
8-18-77	66	62	8.1	24	11	15A	6.0M, 13.3N
8-25-77		34	10.3	7			0.4M
8-26-77	122	37	7.5	7	1		1.3M
8-30-77		76	7.7	14	6	41A, 2F	
8-31-77	66	61	7.8	13	9	40A, 3F	
9-6-77		87	6.1	17	10	133A	7.4N
9-7-77	212	80	6.6	14	5	104A	1.7M
9-13-77		108	5.4	18	13	42A, 26F	9.2N
9-14-77	132	81	5.8	24	16	43A, 15F	6.4N
9-21-77		45	8.3	11			1.8D
9-22-77	133	41	6.6	8			0.1D
9-28-77		44	6.3	13	5		1.8D
9-29-77	40	41	7.2	12	<1		0.1D
10-9-77		40	6.2	11			1.9D
10-10-77	53	27	10.4	8			5.1D
10-17-77		14	9.2	7			
10-18-77	5	15	7.7	5			
10-23-77		13	7.1	24			4.8D
10-24-77	8	12	8.2	21	11		4.8D, 13N
10-31-77		31	8.5	8			3.6D
11-1-77	40	43	9.8	19		23A	5.0D
11-10-77		62	12.1	22	7	132A, 12F	2.3D, 1M, 17.9N
11-11-77	86	64	8.8	26	8	192A, 17F	30N
11-22-77		24	8.0				

(continued)

TABLE D-7. (continued).

Date	TTHM (µg/l)	Chlorine (lb/MG)	Ammonia (lb/MG)	Potassium Permanganate (lb/MG)	Carbon (lb/MG)	Inorganic Coagulant (lb/MG)	Polymer (lb/MG)
11-23-77	28	26	8.5				0.9N
11-29-77		21	9.5				
11-30-77	27	21	8.7				
12-14-77		20	11.6	5			
12-15-77	13	20	10.6	8			
3-28-78		22.9	5.7	42	84	45A, 134F	3.2H, 56N
3-29-78	3	23.7	6.5	46		37A, 64F	3.3H, 57N
4-7-78		20.7	10.4	29	7		56.4N
4-8-78	2	24.6	10.4	29	11		21.3N
4-13-78		67.1	8.3	43	20	58A	54.8N
4-14-78	1	61.6	9.3	26	25	32A	28.9N
4-21-78		12.2	11.4	11	32	20F	31.2N
4-22-78	1	11.9	8.1	10	29	71A, 5F	42.4N
5-1-78		11.3	10.2		14		2.9H
5-2-78	4	13.2	10.2		14		2.1H
5-14-78		12.7	10.0	17	29	16F	5.4H
5-15-78	2	10.4	9.5	13	19	30F	3.8H
5-21-78		20.6	9.2	12	24		2.3H
5-22-78	4	16.7	10.9	24	16		3.9H
6-1-78		6.6	10.5	25	15		1.9H, 7.2N
6-2-78	6	8.7	12.9	23	15		4.9H
7-18-78		8.8	2.3Anhyd.	21		58A	0.1N
7-19-78	70	28.4	2.2Anhyd.	13		105A	
7-23-78		62.9	7.9Aqua	35	14		29.3N
7-24-78	104	57.9	6.7Aqua	39	12		28.5N
7-30-78		37.1	8.8Aqua	9			3.3N
7-31-78	137	37.8	7.4Aqua	6			1.3N
8-11-78		27.2	8.3	8			
8-12-78	38	29.4	8.1	8			1.1N
8-18-78		33.0	8.3				1.1N
8-19-78	37	32.4	10.5				1.4N
8-26-78		31.6	10.2				2.0N
8-27-78	34	24.8	10.5				2.0N
9-2-78		29.3	11.3Aqua		15		3.3N
9-3-78	24	23.6	12.7Aqua		15		3.5N
9-17-78		44.7	8.4Aqua		16	21A, 8F	14.8N
9-18-78	7	48.6	8.3Aqua		14	22A	9.0N
9-25-78		35.9	8.4Aqua	2	13	1A	9.1N
9-26-78	46	30.7	9.8Aqua	1	8		4.4N
10-5-78		22.6	4.5Anhyd.		14		5.2N
10-6-78	35	20.9	3.6Anhyd.		14		0.8H
10-12-78		17.3	4.4Anhyd.		12		21.6N
10-13-78	37	18.0	4.7Anhyd.		8		6.2N
10-21-78		17.6	5.4Anhyd.		10		13.2N
10-22-78	28	16.0	5.7Anhyd.		9		14.5N
10-28-78		16.6	3.7Anhyd.		14		6.5N
10-29-78	32	18.2	3.8Anhyd.		16		7.5N
11-11-78		16.2	11.3Aqua		21		1.9N
11-12-78	42	18.0	10.8Aqua		17		2.1N
11-24-78		15.0	10.4Aqua	3	4		1.6N
11-25-78	49	17.9	12.1Aqua	2			1.5N

Coagulants & Polymers: A = Liquid alum, D = Dow, F = Ferric sulfate, M = Magnifloc, N = Nalco.

lb/MG = pounds per million gallons